Vol. VIII FEBRUARY, 1933 No. 3

THE AMERICAN HEART JOURNAL

PUBLISHED BI-MONTHLY
UNDER THE EDITORIAL DIRECTION OF
THE AMERICAN HEART ASSOCIATION

PUBLISHED BY THE C. V. MOSBY COMPANY, 3523-25 PINE BLVD., ST. LOUIS, U. S. A.
Entered at the Post Office at St. Louis, Mo., as Second-Class Matter.
Additional Entry at Fulton, Mo.

The American Heart Journal

CONTENTS FOR FEBRUARY, 1933

Original Communications

Department of Clinical Reports

In Memoriam

Department of Reviews and Abstracts

The American Heart Journal

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Original Communications

THE MECHANISM OF PRODUCTION OF SHORT P-R INTERVALS AND PROLONGED QRS COMPLEXES IN PATIENTS WITH PRESUMABLY UNDAMAGED HEARTS: HYPOTHESIS OF AN ACCESSORY PATHWAY OF AURICULO-VENTRICULAR CONDUCTION (BUNDLE OF KENT)*

CHARLES C. WOLFERTH, M.D., AND FRANCIS CLARK WOOD, M.D.
PHILADELPHIA, PA.

IN 1930, Wolff, Parkinson and White[1] called attention to a group of cases with the following characteristics: (a) The patients are usually young healthy individuals without evidence of organic heart disease. (b) Their electrocardiograms show short P-R intervals (0.10 second or less), and ventricular complexes with certain characteristics suggesting bundle-branch block. (The QRS complex is widened and slurred, and the T-wave may be opposite in direction from the main deflection of QRS.) (c) In some cases both the P-R interval and the ventricular complex suddenly revert to normal, without change in contour of the P-wave. This may occur spontaneously or when the heart rate is increased by exercise or by atropine administration. When the heart rate slows the abnormal characteristics may return. Vagal stimulation effected a return of aberrant complexes in one case.[1] (d) The patients in this group are particularly liable to attacks of paroxysmal supraventricular tachycardia or paroxysmal auricular fibrillation, during which the ventricular complex assumes a normal configuration.

Prior to the publication of Wolff, Parkinson and White, somewhat similar cases had been reported by Wilson,[2] Wedd[3] and Hamburger.[4] Since that time, Pezzi[5] has reported three of them.

We have had the opportunity of studying nine cases of this type. One other case in our series was furnished by the kindness of Dr. W. B. Porter of Richmond, Va. The significant data concerning them are summarized in the appended case reports. Only two patients in our group had demonstrable organic cardiovascular disease (Cases 7 and 9). Four

*From the Robinette Foundation, Medical Division, Hospital of the University of Pennsylvania.

gave a history of paroxysmal tachycardia. One patient, fourteen years of age, had had such attacks since the age of two years (Case 1). Two individuals had paroxysmal auricular fibrillation (Cases 2 and 10). A reversion of the electrocardiogram to normal could not be produced in any of our cases, either by exercise or by atropine administration. In one patient (Case 1, Fig. 1), the ventricular complex assumed a normal contour during a paroxysm of tachycardia. Graphic records were not obtained during a paroxysm in any other case. In one of the patients with cardiovascular disease (Case 7) electrocardiograms were ob-

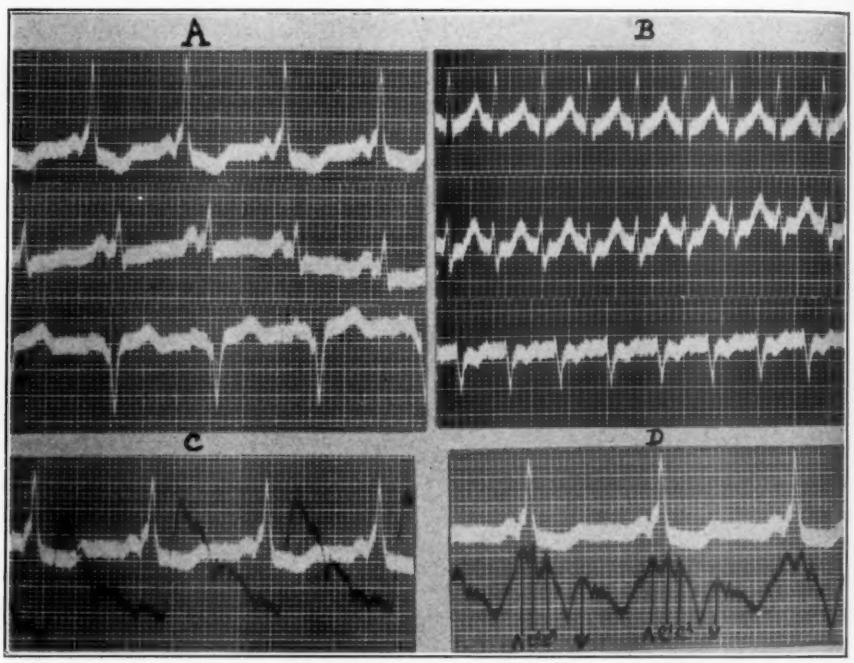

Fig. 1.—Case 1. *A*, Electrocardiographic tracing made on March 22, 1932. The P-R interval has a duration of 0.09 second. The QRS complex is widened and slurred, duration 0.11 second.

B, Electrocardiogram taken April 5, 1932, during a paroxysm of tachycardia. The widening and slurring of the QRS complexes has disappeared. The heart rate is 215 per minute. The electrical axis has not changed.

C, Simultaneous electrocardiogram and carotid pulse curve recorded without parallax. The carotid tracing was made with an optical recording device.[10] The upstroke of the carotid pulse curve takes place 0.08 to 0.09 second after the peak of the R-wave of the electrocardiogram.

D, Simultaneous electrocardiogram and jugular phlebogram recorded without parallax. The phlebogram was made with an optical recording apparatus.[10] The A- and V-waves are readily identified. The C-wave is bifurcated. The upstroke of the second component (C_2) begins 0.08 second after the peak of the R-wave of the electrocardiogram. It therefore occurs at the same time in the cardiac cycle as the carotid upstroke (see Fig. 1 *C*). The upstroke of the first component of the C-wave (C_1), precedes the upstroke of the second component (C_2) by 0.08 to 0.09 second. It precedes the peak of the R-wave of the electrocardiogram by about 0.01 second.

tained on two occasions, eight days apart (Fig. 2). The first tracing was characteristic of the group under consideration; the heart rate was 120. The second showed a different type of complex; the rate was 105. The presence of severe progressive heart disease makes it impossible to

draw any conclusions concerning the effect of rate change upon the occurrence of the characteristic short P-R interval and aberrant ventricular complex in this patient. In the other patient with heart disease (Case 9, Fig. 3) the electrocardiogram in 1927 showed a short P-R interval and wide QRS complex. In 1932 these characteristics had disappeared and could not be made to reappear by vagal stimulation.

Our interest in this group of cases is chiefly centered in an attempt to understand the nature of the abnormal cardiac mechanism by which this unusual electrocardiographic picture is produced. Before under-

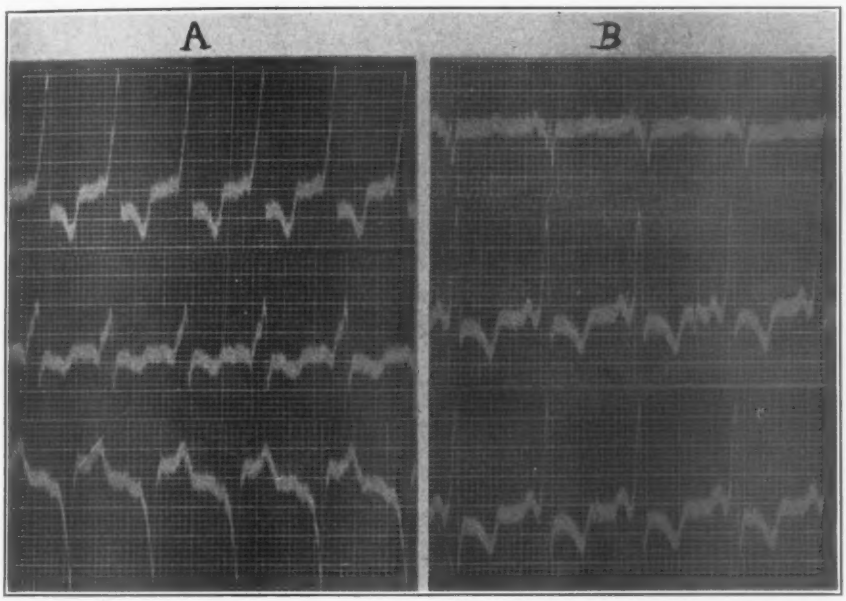

Fig. 2.—Electrocardiograms of Case 7. *A*, Tracing made November 13, 1925. P-R interval 0.08 second. QRS complex widened and slurred in its initial deflection, duration 0.12 second.

B, Tracing made November 21, 1925. P-R interval is still short. The QRS complex is still widened but has changed its contour considerably. The T-waves have also changed markedly. There is probably some overshooting in Leads II and III. This patient had severe progressive cardiovascular disease.

taking a discussion of this question, we wish to emphasize three additional features presented by these patients: (a) The period elapsing from the beginning of the P-wave to the end of the QRS complex is well within normal limits, despite the aberration of the ventricular complex. (b) If the P-R interval lengthens, the QRS complex simultaneously shortens to an equal extent. Consequently in a given case, the period from the beginning of the P to the end of QRS remains substantially the same throughout, whether the electrocardiogram is normal or abnormal. (Cf. Wolff, Parkinson and White,[1] Cases 3 and 4.) (c) In the cases so far reported, the slurring of the QRS complex has always involved the initial deflection. The terminal portion may or may not be slurred.

Two hypotheses have been proposed to explain the abnormal cardiac mechanism:

I. Wolff, Parkinson and White[1] have described it as a bundle-branch block. Such a view was probably suggested by the fact that widened and aberrant QRS complexes have always been associated with the conception of defective intraventricular conduction. However, this explanation is untenable for the following reasons: (1) The time interval from the beginning of P to the end of QRS does not exceed that of normal cases. Furthermore, when the mechanism reverts to normal, this interval shows no material change—since the lengthening of the P-R interval and the

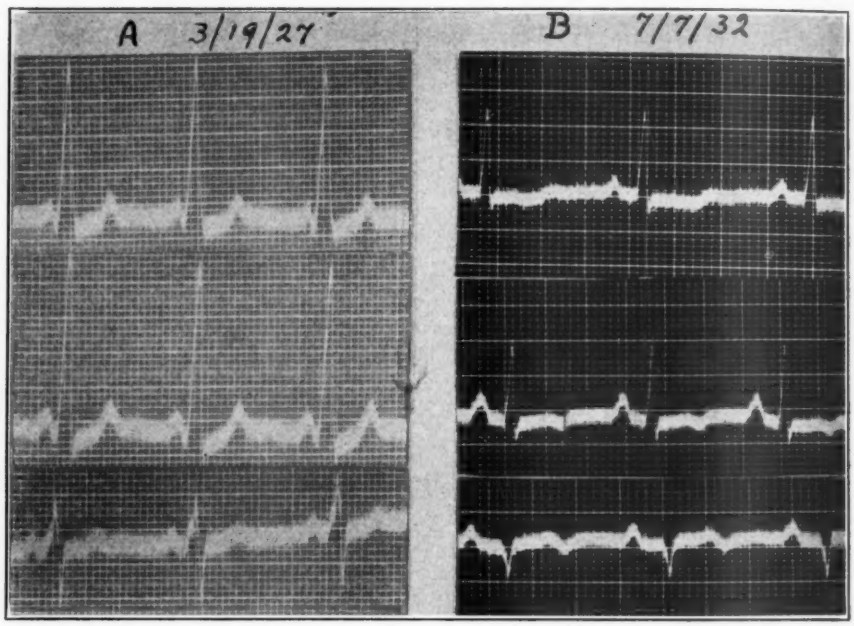

Fig. 3.—Electrocardiograms of Case 9. *A*, Tracing made March 19, 1927. The P-R interval is 0.10 second. The QRS complex is widened and slurred in its initial deflection, duration 0.12 second.

B, Tracing made July 7, 1932. The P-R interval is now normal, 0.18 second. The QRS complex is of normal width, 0.06 second. The abnormal characteristics did not return on vagal stimulation. This patient has definite rheumatic heart disease.

shortening of the QRS complex are approximately equal. (2) The effect upon the electrocardiogram of change in cardiac rate in these cases differs fundamentally from the effect of rate change upon true bundle-branch block. Herrmann[6] has reported cases of paroxysmal bundle-branch block, in which the conduction defect did not appear until a critical rate was exceeded. We have had a similar experience in a few cases. Moreover, it is well known that defects in intraventricular conduction are often observed in the most premature beats of auricular fibrillation, and in auricular extrasystoles which closely follow the preceding cardiac condition. Therefore, in the presence of an incipient

bundle-branch defect, an increase in heart rate should tend to cause the defect in conduction to appear, not to disappear.* If the cases under consideration really were instances of bundle-branch block, the aberration of the QRS complex should be present during paroxysms of rapid heart action, not absent. (3) The bundle-branch block hypothesis fails to explain: (a) the predisposition of these patients to attacks of paroxysmal tachycardia and fibrillation; (b) the fact that this condition is apparently unrelated to cardiac damage; and above all (c) the short P-R interval. An analysis of the tracings of these individuals shows that *the abnormality of the QRS complex consists, not of a block or delay, but of an actual early arrival in the ventricular muscle of the impulse from the auricle.*

II. Pezzi[5] objects to the bundle-branch block hypothesis because it does not account for the short P-R interval. He proposes another explanation, namely, that the abnormal mechanism consists of a "paraseptal rhythm." By this term he means a rhythm whose pacemaker is situated in the neighborhood of Tawara's node, in the auricular septum. The etiology of this abnormal rhythm is considered to be an irritative lesion involving the "paraseptal" region. Pezzi accounts for the various phenomena as follows: (1) The short P-R interval is due to the proximity of the pacemaker to the junctional tissues. (2) The P-wave is upright and not inverted (as one would expect, with a paraseptal pacemaker), because the impulse reaches the auricular muscle from the normal direction. The author is not absolutely clear in his exposition of how this is brought about. He implies, however, that the impulse travels direct from the paraseptal pacemaker to the sino-auricular node over a special "sinonodal pathway" before reaching the auricular muscle. It then invades the auricle from the region of the sino-auricular node. This explanation helps further to account for the shortness of the P-R interval, since a period elapses between the discharge of the impulse from the paraseptal pacemaker and its arrival in the auricular muscle via the sinonodal pathway and the sino-auricular node. (3) The aberrant QRS complex is explained as follows: The author assumes the existence of special septoventricular conduction pathways: that, beginning in the node of Tawara, there is a complete functional separation of the junctional tissues into those sending impulses to the right ventricle, and those transmitting them to the left. He believes, therefore,

*This statement must be qualified as follows: Vagal stimulation is known to cause (a) Slowing of the heart rate, which per se aids junctional conduction, and (b) impairment of auriculoventricular conduction. If, therefore, a retardation of rate is vagal in origin, it might be accompanied by impaired conduction of the excitatory impulse through the junctional tissues; since it is theoretically possible for (b) to overshadow (a). Danielopolu[11] has actually observed this phenomenon in a bundle branch. However, if the widened QRS complexes in these cases are to be explained by vagal inhibition of conduction, how can one account for the shortened P-R interval? The vagus can hardly be expected to have a "paradoxical effect":[1] both to accelerate and to retard conduction at the same time. Moreover, in one of our patients the vagus was pressed upon in the neck during an attack of paroxysmal tachycardia (Case 1). Thus, presumably, both factors (a) and (b) were operating simultaneously to impair conduction. Nevertheless, the QRS complexes, which were normal during the paroxysm, remained so despite the vagal stimulation.

that the impulses to one ventricle can be blocked by a lesion situated at any point in one of the "septoventricular conduction pathways": (a) In the bundle branch; (b) in the bundle of His, or (c) in the node of Tawara itself. With the foregoing speculation as a point of departure, Pezzi states that the lesion responsible for this group of cases is situated in the neighborhood of Tawara's node but extends to involve part of the node and its "annexes." Thus it blocks one septoventricular pathway at its head, in the node of Tawara, and produces an electrocardiographic picture similar to that of a bundle-branch block. (4) The "irritative lesion in the paraseptal region" is considered to be responsible for the frequently observed paroxysms of tachycardia. (5) None of Pezzi's cases showed a transition from abnormal complexes to normal ones. He explains the occurrence of this phenomenon in the cases reported by Wolff, Parkinson and White[1] by supposing the lesion in those instances to be a very mild one (almost entirely "functional"). A release of vagal tone caused it to disappear, thereby allowing normal conduction through the node of Tawara. Although he does not say so, he must believe that when the transition occurs, the sino-auricular node assumes its normal function of pacemaker.

If all the physiological substructure upon which Pezzi's hypothesis is based were sound, the unusual electrocardiographic picture might be accounted for on this basis. However, the following facts make one question the validity of his explanation: (1) Although the existence of a special sinonodal pathway has been advocated by some authors,* it seems strange that (a) it is not brought into play in other cases of nodal rhythm: (in the vast majority of cases of nodal rhythm, the P-wave is inverted in Leads I and II), and (b) that it comes into play in every single case in this group: (not one case in all those reported shows an inverted P-wave in Leads I or II). (2) There is no evidence of the existence of "special septoventricular conduction pathways" to each ventricle, which are functionally separated from each other as high as the node of Tawara. Lewis[7a] states, "It is a matter of indifference whether the impulse originates in the normal pacemaker, in the substance of either auricle, or in the A-V node or bundle down to the point of its subdivision; the ventricle is activated in precisely the same way and the resultant curve is of constant form." If functionally isolated "special septoventricular conduction pathways" existed, one would expect aberration of the ventricular complex to be the rule with the pacemaker situated in the node, or in the bundle of His: the pacemaker would have to be located in one of these pathways and should be incapable of transmitting impulses to the other. (3) It is inconceivable that a dislocation of the pacemaker from the paraseptal region to the sino-auricular node could take place without any change: (a) in the rate or rhythm, (b) in the interval from the beginning of the P-wave to the

*It is not accepted by Lewis.[7d]

end of the QRS complex, or (c) in the contour and direction of the P-wave. (Cf. Wolff, Parkinson and White,[1] Cases 3 and 4.) In our experience, whenever the pacemaker has moved from the region of the node of Tawara to the sino-auricular node, the P-wave has always shown a change in contour and direction. (4) The second objection to the bundle-branch block hypothesis seems applicable to Pezzi's explanation. (5) Pezzi's hypothesis might account for paroxysms of nodal tachycardia. However, it still leaves unexplained the origin of paroxysms of auricular fibrillation, which occurred in one case reported by Wolff, Parkinson and White[1] and in two of our patients. (6) Pezzi speaks of the etiological factor as a "lesion." However, all indications point to an absence of any acquired cardiac damage.*

In view of the foregoing considerations, the two hypotheses which have been proposed seem inadequate to explain all the features presented by this group of cases. If, however, the assumption is made that an accessory pathway for auriculoventricular conduction exists, besides that furnished by the bundle of His, the phenomena thus far observed may be accounted for.

Many years ago, Kent[8] described a structure bridging the auriculoventricular groove at the right lateral border of the heart, connecting the right auricle and right ventricle. It was first observed in newborn rats, but later also in man. Photomicrographs of its appearance in the human heart are available. A statement concerning the frequence of its occurrence in man has not been found. At the upper end of this connection is a node, comprised of tissue similar to that found in the node of Tawara. The muscular bridge begins at the lower border of this node. It is formed by muscle fibers derived from two or three different layers of the ventricular wall. Kent demonstrated to his own satisfaction that impulses could be conducted from auricle to ventricle by this structure in several species of mammals. His conclusions seem justified, namely, that there is a muscular connection between the auricles and ventricles at the right lateral border of the mammalian heart; that this connection has been shown to conduct impulses from auricle to ventricle in mammals and should be capable of doing so in man.

Lewis[7b] states that "There is no reason to believe that the structures described by Kent take part in conducting impulses from auricle to ventricle. The physiological evidence is strongly opposed to this idea, and such anatomical evidence as we possess is insufficient to give the view any material support." Consequently interest in the "bundle of Kent" appears to have waned. It seems to us, however, that the assumption of conduction of the excitatory process by Kent's bundle,† in addition to its conduction by the conventional pathway through the bundle

*Wolff, Parkinson and White[1] observed that a compensatory pause regularly followed a ventricular extrasystole in these cases. They cited this as evidence in ruling out nodal rhythm. We agree with Pezzi that this fact does not rule out nodal rhythm.

†Or some analogous structure.

of His, offers a satisfactory explanation for these cases. It is necessary to assume in addition that this structure is sufficiently developed to function in only a few individuals.

On the basis of a functioning bundle of Kent, the various phenomena observed in these cases may be accounted for as follows:

(1) The shortness of the P-R interval is due to the short direct pathway from auricle to ventricle through Kent's bundle.

(2) The premature invasion of a certain section of the ventricular muscle by this impulse causes (a) a slurring of the initial deflection of the QRS and (b) a widening of the QRS complex at the expense of the P-R interval. (See Fig. 4.)

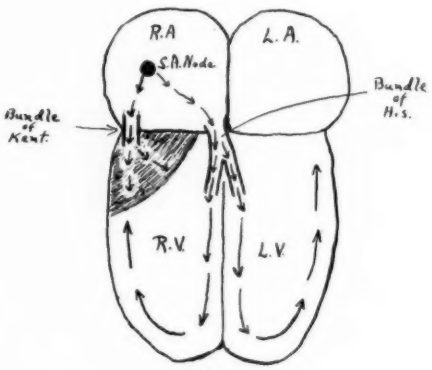

Fig. 4

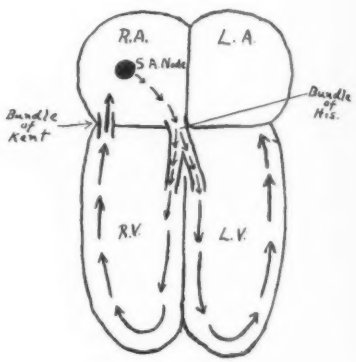

Fig. 5

Fig. 4.—Schematic representation to illustrate the hypothesis of premature transmission of the impulse through the bundle of Kent to the right ventricle. The shaded area represents the section which is activated before the impulse reaches the ventricles through the bundle of His. This mechanism would account for the short P-R interval, the widening of the QRS complex and the slurring of its initial deflection.

Fig. 5.—Schematic representation showing the path of an impulse which might be responsible for exciting a paroxysm of supraventricular tachycardia or auricular fibrillation.

(3) In some cases, conductivity in the bundle of Kent may not be highly developed. Consequently, when subjected to the passage of impulses at a rapid rate, as during paroxysmal tachycardia, it may fail to function. This seems to offer a more satisfactory explanation for the transition from abnormal to normal complexes than that furnished by either of the previous hypotheses (q.v.).

(4) The frequence of paroxysmal tachycardia and paroxysmal fibrillation may be accounted for on the basis of this hypothesis. Kent showed that retrograde conduction through the "right lateral bundle" was possible in newborn rats.[8d] Under certain circumstances, therefore, a retrograde impulse might travel from ventricle to auricle at a time when the physiological state of the auricular muscle would favor the inception of an abnormal rhythm. (See Fig. 5.)

(5) The assumption of a functioning bundle of Kent does away with

the necessity of postulating a lesion, or a defect in conduction, in youthful patients, without evident cardiac damage.*

(6) As we have stated above, when the mechanism changes from a short P-R interval and a wide QRS complex to a normal P-R interval and a normal QRS complex, the duration of the interval from the beginning of the P-wave to the end of the QRS complex tends to remain constant. (Cf. Wolff, Parkinson and White,[1] Cases 3 and 4.) If these facts are confirmed by more extended observation, only one interpretation seems possible, namely: that the variable factor is early aberrant conduction from auricles to ventricles. This does not interfere with conduction through the junctional tissues (the node of Tawara and bun-

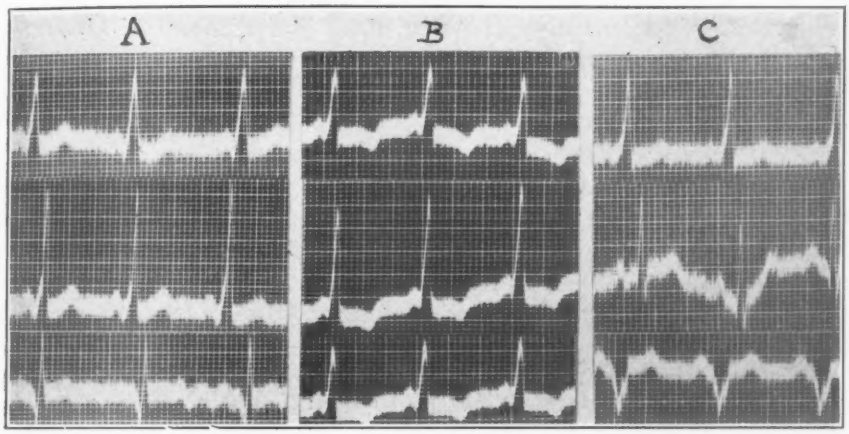

Fig. 6.—*A*, Electrocardiogram of Case 4, taken December, 1929. The P-R interval is 0.08 second. The QRS complex is widened and its initial portion is slurred, its duration being 0.10 second. There is a Q-wave in Lead III.

B, Electrocardiogram of Case 6, taken September 21, 1931. The P-R interval is 0.08 second. The initial portion of the QRS complex is slurred. The complex has a duration of 0.08 second.

C, Electrocardiogram of Case 5 taken January 7, 1929. The P-R interval is 0.09 second. The QRS complex is widened and slurred, duration 0.11 second.

dle of His), but alters the duration and form of the initial portion of the ventricular complex in direct correspondence with the prematurity of arrival of the aberrant impulse in the ventricular muscle.

(7) If early transmission of the impulse by way of Kent's bundle is the mechanism responsible for this syndrome, (A) there should be definite asynchronism in the contraction of the two ventricles, and (B) the left ventricle should contract at the normal time in the cardiac cycle, whereas the right ventricle should contract prematurely. The data thus far obtained in this group of patients suggest that these things actually occur.

*It is of interest to note that this type of electrocardiogram seems to be quite unusual after the age of forty years. This raises the question as to whether these patients die young (which seems unlikely, since they usually have no evidence of cardiovascular damage); or whether the mechanism responsible for the short P-R interval and the aberrant QRS complex becomes less capable of functioning with advancing years (cf., Case 9, and Wolff, Parkinson and White,[1] Cases 3 and 8).

(A) The evidence for asynchronous contraction of the ventricles is as follows: (a) The electrocardiographic tracings suggest it; (b) a marked reduplication of the first heart sound has been noted in our last two cases. Although no special attention had been paid to this feature in the other six, the records of two state that the first heart sound "was split"; (c) in the one patient in whom a jugular phlebogram was made, there is a bifurcation of the C-wave with an interval of 0.09 second between its two components (Fig. 1 *D*).* It is well known that optically recorded jugular pulse curves in presumably normal individuals may show a bifurcation of the C-wave. The two elements of this bifid wave are, first, a "venous" wave produced by right ventricular contraction and transmitted up the superior vena cava to the jugular vein; and, second, an arterial wave, which is a transmitted pulsation from the carotid artery. In normal individuals, the interval between the upstrokes of the two peaks of the C-wave does not exceed 0.048 second.[9, 10] Therefore, the interval (0.08 to 0.09 second) obtained in the patient under consideration is nearly twice the top normal figures. It is comparable to that seen in cases of true bundle-branch block.[10]

(B) The evidence that the left ventricle contracts at the normal time in the cardiac cycle, whereas the right ventricle contracts prematurely, is as follows: An optically recorded jugular phlebogram and simultaneous electrocardiogram were photographed on the same film without parallax (Fig. 1 *D*). A simultaneous carotid pulse curve and electrocardiogram were obtained in a similar manner (Fig. 1 *C*). A comparison of the carotid and jugular curves with the electrocardiographic tracing shows that: (a) The upstroke of the carotid wave and the upstroke of the second element of the jugular C-wave, C^2, occur simultaneously in the cardiac cycle at a point 0.08 second after the peak of the R-wave. There is little doubt that both these waves are produced by left ventricular activity. Moreover, the interval separating their upstrokes from the peak of the R-wave is normal.[7c, 10] Therefore, one is probably justified in assuming that left ventricular contraction occurs at a normal time in the cardiac cycle and causes the second peak of the C-wave in the jugular phlebogram. (b) The upstroke of the first element of the jugular C-wave, C^1, precedes the aforementioned left ventricular phenomena by 0.08 to 0.09 second, and precedes the peak of the R-wave by 0.01 second. There is no doubt, therefore, that this wave clearly precedes left ventricular contraction. Since C^1 is almost certainly related to right ventricular activity, the conclusion is difficult to escape that the right ventricle contracts prematurely in the cardiac cycle and at a considerable interval before the left. A great deal of emphasis cannot be

*A jugular phlebogram published by Wolff, Parkinson and White[1] in a similar case does not show a bifurcated C-wave. However, in order to record this phenomenon, an optical recording apparatus must be used, and special attention must be paid to the pressure at which the recording capsule is applied to the jugular vein. By increasing the pressure, the venous element of the C-wave can be diminished or abolished, and the arterial element can be exaggerated.

placed upon the data from a single case. Further observations of this type are necessary. Should it be found that these phenomena occur with regularity, the hypothesis we have presented should be considerably strengthened.

The direction of the initial deflection of the QRS complex deserves mention. If premature activation of a certain constant section of the right ventricle through the bundle of Kent is the cause of the slurring of the initial deflection of the QRS complex, one might expect to find this initial deflection to be in the same direction in every patient. Analysis of the cases so far reported shows that this expectation is not fulfilled. In Lead I, the initial deflection in every case has been upright. In Lead II, 22 have been upright, 4 have been down. In Lead III, 12 have been upright, 14 have been down.* However, this does not constitute a major objection to the hypothesis herein proposed. Variation of position and shape of the heart, or a variation in the location of the bundle of Kent† might readily account for these differences.

The case reported by Hamburger[4] merits a brief discussion, because it presents certain phenomena which have not been observed in any other instance of this syndrome. The presence of an acute febrile illness and a paroxysm of ventricular tachycardia suggests that complicating factors are present in this case, which makes it differ in certain respects from other similar ones. The features of particular interest to us are the following: (1) This is the only case on record in which the abnormal complexes have persisted during a paroxysm of supraventricular tachycardia, if we admit the correctness of this electrocardiographic diagnosis. (It is possible, however, that the rhythm is a simple tachycardia.) (2) During the "paroxysmal tachycardia" the rhythm is frequently interrupted by beats with a normal P-R interval and a normal ventricular complex. An examination of Hamburger's tracings shows that: (a) The interval from the beginning of the P-wave to the end of the QRS complex remains quite constant, whether the ventricular complex is normal or abnormal. This suggests that the beat with the normal ventricular complex is a sequential beat, not a nodal beat (cf. Hamburger's explanation). (b) There is an inverted P-wave after each normal QRS complex, more apparent in Leads II and III. (c) The interval between the beginning of such an aberrant P-wave and the next normal P-wave slightly exceeds the length of the usual auricular cycle. This disturbance in the rhythm is therefore like that seen when any auricular rhythm is interrupted by a beat from a different auricular focus.

The only satisfactory explanation of these phenomena which occurs to us, is that afforded by the "bundle of Kent hypothesis." It might

*Case 9 of Wolff, Parkinson and White[1] is not included in this analysis, since Lead III is not available.

†Kent does not deny the existence of other analogous auriculoventricular connections.

be outlined as follows: In Hamburger's patient, the bundle of Kent has a highly developed conductivity, being capable of conducting impulses at a rate of 150 per minute. However, at this rapid rate it occasionally fails to function. At such a time the impulse from auricle to ventricle is conducted solely through the bundle of His, hence the P-R interval and QRS complex suddenly become normal, although the interval from the beginning of the P-wave to the end of the QRS complex remains substantially unchanged. Now, by the time the impulse has extended throughout the ventricle, the bundle of Kent, having had a rest period, is once more conductive. It therefore conducts the impulse in a retrograde direction back to the auricle and gives rise to an inverted P-wave directly following the normal QRS complex.* This auricular beat has the same effect upon the pacemaker that an ordinary auricular extrasystole would have. It abolishes the impulse which is forming and gives rise to a pause, since an entirely new impulse must be built. After this the "paroxysmal tachycardia" begins once more. The demonstration of probable retrograde conduction through the bundle of Kent in Hamburger's case affords support to the explanation we have suggested to account for the frequence of paroxysmal tachycardia in these cases (q.v.).

SUMMARY

(1) In about one out of a thousand electrocardiograms, a case may be encountered which exhibits an abnormally short P-R interval associated with a widened QRS complex, markedly aberrant in its initial portion.

(2) It is necessary, as stressed by Wolff, Parkinson and White,[1] to recognize that this type of tracing may occur in the absence of acquired cardiac damage.

(3) Many of these patients are subject to paroxysms of tachycardia and auricular fibrillation.

(4) An analysis of the tracings of these cases reveals that their characteristics cannot be explained, by the hypothesis that they are due either to bundle-branch block (Wolff, Parkinson and White[1]), or to "paraseptal rhythm" (Pezzi[5]).

(5) The abnormal mechanism consists, not of a delay or block, but of an actual acceleration of the passage of the impulse from the auricle to a section of the ventricle.

(6) All the data so far obtained are in keeping with the possibility that an accessory pathway of A-V conduction (such as that described by Kent,[8] between right auricle and right ventricle) could be responsible for the phenomena manifested by these cases.

(7) We therefore propose this new hypothesis. We recognize clearly

*It is not improbable that certain cases of so-called reciprocal rhythm are explainable by retrograde conduction through the bundle of Kent.

that it is only an *hypothesis*. Nevertheless it seems a strikingly satisfactory one and accounts for all the phenomena thus far observed in this syndrome.

CASE REPORTS

CASE 1.—V. D., a white female, aged fourteen years, had suffered from paroxysms of tachycardia about once a week since the age of two years. She was first seen on March 22, 1932. Examination showed no evidence of cardiovascular disease. Both heart sounds were reduplicated. The orthodiagram was normal.

The electrocardiographic studies are shown in Fig. 1. Vagal pressure did not cause any change in the tracing. Exercise increased the heart rate to 125 beats per minute, without changing the electrocardiogram. On April 5, 1932, the patient was studied during a paroxysm of tachycardia. Fig. 1 *B* shows the tracing. Vagal pressure did not stop the paroxysm nor change the electrocardiogram. Further studies are shown in Fig. 1 *C* and *D*.

CASE 2.—R. B., a white male, aged thirty-four years, had experienced occasional paroxysms of rapid heart action since the age of eighteen years. In February, 1932, while playing golf, he suddenly became conscious of rapid irregular heart action. Dr. Richard Anderson of Burlington, N. J., examined him and found that he had "an auricular fibrillation with a pulse deficit of about 60." This paroxysm continued for four days. Dr. Anderson referred the patient to one of us on March 10, 1932. There was no evidence of cardiovascular disease. Both heart sounds were markedly reduplicated. The orthodiagram was normal.

An electrocardiogam was made on March 10, 1932. It is not reproduced since it markedly resembles the tracing of Case 1 (Fig. 1). The P-R interval is 0.08 second. The QRS complex is widened and its initial deflection is slurred—duration 0.12 second. The T-waves are opposite in direction to the initial deflection of QRS. Exercise increased the heart rate to 125 beats per minute, without altering the electrocardiogram.

CASE 3.—A. B., was a white male, aged nineteen years, a student at the University of Pennsylvania. He had his electrocardiogram taken on December 13, 1929, when a routine study of a series of normal students was being made. He had no complaints and no signs of cardiovascular disease. The orthodiagram was normal. The first heart sound was markedly reduplicated. The electrocardiogram is not reproduced since it resembles that of Case 1 (Fig. 1). The P-R interval is 0.08 second. The QRS complex is widened and its initial deflection is slurred, duration 0.12 second. Exercise increased the heart rate to 145 beats per minute and amyl nitrite administration raised it to 155, without changing the electrocardiogram. A reexamination was made February 13, 1931. No change had taken place in the interval.

CASE 4.—W. H. L., Jr., a white boy of thirteen years, was found to have an abnormal electrocardiogram during a routine medical examination. He had no complaints and no signs of cardiovascular disease. The orthodiagram was normal. An electrocardiogram was made in December, 1929 (Fig. 6 *A*). Exercise increased the heart rate to 130, without changing the electrocardiogram. There has been no change in the state of his health since the first examination.

CASE 5.—T. B. G., a college boy of twenty-one years, had rowed on the crew for three years. He had no signs or symptoms of cardiovascular disease. His electrocardiogram (Fig. 6 *C*) was taken January 7, 1929, during a routine study of the hearts of a group of college athletes. No follow-up examination has been made.

CASE 6.—H. B., a white woman of thirty-five years, had suffered from fatigue and undernutrition for several years. She had experienced "choking spells" for

two years, lasting from a few minutes to several hours. Her heart rate had never been taken during one of these spells. She was first seen September 21, 1931. She had no evidence of cardiovascular disease. The orthodiagram was normal. Her electrocardiogram is shown in Fig. 6 *B*. The heart rate was increased to 125 by exercise, and to 155 by amyl nitrite, without changing the electrocardiogram. She was last heard from on July 5, 1932; at that time she was suffering from "nervous exhaustion."

CASE 7.—H. L., a white male of twenty-seven years, was a patient in the University of Pennsylvania Hospital from November 12 to 30, 1925. He had evidence of severe congestive heart failure and chronic glomerulonephritis. The heart was markedly enlarged. At one time a pericardial friction rub was heard. The notes state that the first heart sound was "markedly split." He had suffered with "spells of palpitation" for four weeks. Short paroxysms of tachycardia were noted while he was in the hospital. Two electrocardiograms were taken (Fig. 2 *A* and *B*). The patient grew progressively worse and signed his release on November 30, 1925. He probably died shortly thereafter.

CASE 8.—(We are able to report this case through the kindness of Dr. W. B. Porter of Richmond, Virginia, who sent us the records.) D. A., was a white boy of fourteen years. During a routine examination on March 21, 1931, he was found to have an abnormal electrocardiogram. He had no complaints and no evidences of cardiovascular disease. The electrocardiogram is not reproduced because it is very much like that of Case 6 (Fig. 6 *B*). The P-R interval is 0.06 second. The QRS complex is widened and its initial deflection is slurred, duration 0.12 second.

CASE 9.—L. K., a white male is now twenty-eight years old. He was first seen on March 28, 1927, when he was a patient in the Hospital of the University of Pennsylvania with acute rheumatic fever. His rheumatic history dated back to 1917, when he had his first acute attack. In 1927 he had evidence of moderate cardiac enlargement; the blood pressure was 140/40 mm. There were signs of aortic insufficiency and mitral insufficiency and stenosis, but no evidence of congestive failure. He was discharged May 28, 1927. He was seen again on July 7, 1932. His rheumatic infection had apparently been quiescent for at least four years. The cardiovascular findings were similar to those found in 1927. His functional classification is now Class II-A. Electrocardiographic studies were made March 19, 1927, and again July 7, 1932. The former (Fig. 3 *A*) showed a short P-R interval and wide QRS complex. The latter (Fig. 3 *B*) showed no abnormality of the P-R interval or QRS complex. Vagal stimulation, by pressure in the neck and ocular pressure, did not cause any change in the electrocardiogram. The interval from the beginning of the P-wave to the end of the QRS complex is 0.22 to 0.24 second in both tracings.

CASE 10.—(We are able to report this case through the kindness of Dr. David A. Cooper.) S. G. was a white male, aged sixty years. He was first seen in 1927 on account of attacks of palpitation and dizziness. He was seen by a physician in one of these attacks on November 11, 1930, and was found to be fibrillating. A diagnosis of myocardial disease was based upon the occurrence of paroxysmal auricular fibrillation. He was first seen by us on January 29, 1930. An electrocardiogram showed a P-R interval of 0.09 second, and a QRS complex widened and slurred in its initial portion, duration 0.12 second. The tracing is not reproduced since it is of the type shown in Fig. 1, Case 1. There is a certain amount of doubt as to the presence of cardiovascular disease in this patient. The blood pressure varies from 120/75 to 165/90 mm. There has been no progression in his symptoms. He is leading a fairly normal life without discomfort. The heart is "possibly slightly enlarged to the left." There are occasional extrasystoles.

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CORONARY EMBOLISM*†

Otto Saphir, M.D.
Chicago, Ill.

EMBOLISM of a coronary artery is a very unusual occurrence. In a recent review of coronary sclerosis, Benson[3] stresses its rarity. The embolus may consist of air, fat, bacterial vegetations from heart valves, particles loosened from atheromatous lesions or broken-up thrombi. Only this latter type of embolus will be referred to in this paper. In most cases on record the source of such an embolus was either a mural thrombus in the sinus of Valsalva or ascending aorta, or vegetations from the aortic or the mitral valve. My purpose is to relate three instances of coronary embolism as proved by autopsy, and to review critically the literature of coronary embolism. Special attention is given to the source of the embolus, to its mechanism and to the type of death, whether occurring slowly or suddenly.

HISTORICAL

Virchow[31] in 1856 was the first to describe coronary embolism. In a very short article on emboli in blood vessels, he referred to a female patient, twenty-seven years old, revealing at autopsy a recent endocarditis of the mitral valve. On gross inspection of the heart, emboli were noted in the coronary arteries. No reference is made as to whether the patient died suddenly.

Hammer[10] in 1878 reported a case of coronary thrombosis in a thirty-four-year-old male. From his description, however, it is more likely that the lesion in question was an embolus rather than a thrombus. There also was endocarditis of the aortic valve and a thrombus in the sinus of Valsalva corresponding to the right aortic cusp. The author did not mention the type of endocarditis. The patient apparently survived the embolism for eighteen hours.

Huber[12] in 1882 described an embolus in the descending branch of the left coronary artery in a sixty-four-year-old male. The patient died suddenly. The origin of the embolus was a thrombus in the main stem of the left coronary artery. Three similar cases were mentioned, but no details given.

Korczyński[17] in 1887 referred to a recent embolus in the circumflex branch of the left coronary artery. He did not definitely state the source of the embolus, but mentioned a chronic endocarditis of the aortic

*From the Department of Pathology of the Nelson Morris Institute of the Michael Reese Hospital and of the University of Illinois Medical School, Chicago, Illinois.
†Aided by grant from the John D. Herz Fund.

valve. The patient was a female, thirty-eight years old, who died suddenly.

Hektoen[11] in 1892 noted an embolus in the left coronary artery at the site of its division into the descending and circumflex branches in a thirty-two-year-old male who had died suddenly. The source of the embolus was a parietal thrombus in the aorta.

Oestreich,[24] in the same year, described an embolus occluding the mouth of the left coronary artery. This case will be referred to later.

Rolleston[27] in 1896 mentioned the case of a seventeen-year-old male patient dying suddenly. An embolus was found in the descending branch of the left coronary artery, the source of which was a ventricular thrombus.

Chiari[6] in 1897 referred to an embolus in the main left coronary artery in a thirty-two-year-old man. The source of the embolus was apparently a thrombus occurring on a small atheromatous ulcer in the aorta. An organizing thrombus was found occluding the orifice of the main right coronary artery. The patient had died suddenly.

Welch[32] in 1899 described the sudden death of a thirty-six-year-old female. There was an embolus in the descending branch of the left coronary artery. He did not mention specifically the source of the embolus, but stated that there were old and recent vegetations on the mitral valve and fresh vegetations on the aortic valve.

Thorel[30] in 1903 held thromboendocarditic excrescences in the sinus of Valsalva corresponding to the left aortic cusp responsible for an embolus in the coronary artery. No reference was made to the exact location of the embolus or to the type of death.

MacCallum[21] in 1905 reported a case of a middle-aged male who died suddenly. There was a vegetative endocarditis of the mitral valve and an embolus in the mouth of the left coronary artery.

Lamb[19] in 1913 described, in a case of vegetative and ulcerating aortic endocarditis, vegetations plugging the mouth of the left coronary artery. The patient, a male thirty-five years old, died suddenly.

Gallaverdin and Dufourt[8] in 1913 mentioned an embolus in the descending branch of the left coronary artery in a male patient sixty-three years old. The death did not occur suddenly. There was an old myocardial scar with mural thrombi. Also, without giving detailed references, they mention a case of Leclerc in which an embolus was found in the circumflex branch of the left coronary artery in a patient who likewise had an infectious endocarditis.

Kaufmann[15] in 1922 mentioned a case of sudden death in a male patient thirty-five years of age. There was an embolus in the descending branch of the left coronary artery. A thrombus was found on the aortic intima just above the posterior cusp of the aortic valve.

Kusnetzowsky[18] in 1923 found an aneurysm of the heart in a fourteen-year-old boy. Though the author mentioned a coronary embolus as a

possible cause of the aneurysm, no definite statements were found in this report to justifiy the assumption of an embolus. There was no statement as to whether death was protracted or sudden.

Rindfleisch[26] in 1924 found an aneurysm in a thirty-six-year-old male. He believed that an embolus in the coronary artery had produced the aneurysm. The embolus, however, was not described in this paper. Yet the author stated that it would be difficult to say where the embolus originated. This was not a case of sudden death.

Benson and Hunter[4] in 1925 attributed fourteen instances of coronary occlusion to embolism but gave no details.

Wolff and White[34] in 1926 described three instances in each of which the source of embolus was an endocarditis. The ages were twenty-three, thirty-one and forty-six years respectively. In two of these cases death occurred suddenly, while in one no reference was made as to the type of death. They also reported a fourth case which will be discussed later.

Murray[23] in 1926 referred to a young man dying unexpectedly. One of the coronary arteries was plugged by an embolus. The author did not designate which coronary artery was involved. Vegetations were found on the aortic intima close to the orifice of one of the coronary openings.

Bopp[5] in 1926, in an article entitled "A Report of a Case of Coronary Embolism With Rupture of the Heart," described a sclerosis of the left coronary artery with obstruction of the lumen, apparently produced by a calcareous mass. In his description there is nothing to indicate the presence of a possible source of an embolus in the coronary artery. The patient was forty-six years old, showed a rupture of the heart, and died suddenly.

Table I is included to summarize only those cases of coronary embolism which were proved as such at the autopsy and which were reported with more details.

Table I indicates that death in the majority of patients occurred suddenly. It also shows that the left coronary is the most commonly involved artery, especially its descending branch.

As to the general views expressed on this subject, it should be mentioned that Marie[22] in 1896 stated that there is only one unquestionable case of coronary embolus on record. This is the case of Virchow.[31] Welch[32] in 1899 said that coronary embolism is far less frequent than thrombosis, but Marie's[22] position that scarcely more than one or two of the reported cases of coronary embolism are free from criticism seemed too extreme. Gallavardin and Dufourt[8] in 1913 mentioned that only three or four cases of coronary embolism are on record. Allbutt[1] in 1915 stated that embolism in the coronary vessels is probably a very rare event. Kaufmann,[15] Dietrich,[7] Jores,[13] and Kirch[16] also stressed the rarity of coronary embolism.

It might be interesting to mention in this connection that Romberg[28]

in 1925 discussed embolism and thrombosis of the coronary arteries in the same chapter, without especial differentiation between the frequency of the occurrence of each disease.

This survey of the literature indicates the rarity of coronary embolism, at least if one judges from the scanty case reports. Several of the re-

TABLE I

AUTHOR	YEAR OF PUBLICATION	AGE	SEX	SOURCE OF CORONARY EMBOLUS	BRANCH OF CORONARY ARTERY INVOLVED	TYPE OF DEATH
Virchow	1856	27	Female	Recent endocarditis	Several branches	?
Huber	1882	64	Male	Thrombus in main left coronary artery	Descending branch of left coronary artery	Sudden
Koreczyński	1887	38	Female	Possibly an endocarditis	Descending branch of left coronary artery	Sudden
Hektoen	1892	32	Male	Parietal thrombus of aorta	Left coronary artery at site of division into the descending and circumflex branches	Sudden
Rolleston	1896	17	Male	Thrombus in left ventricle	Descending branch of left coronary artery	Sudden
Chiari	1897	32	Male	Parietal thrombus of aorta	Main stem of left coronary artery	Sudden
Welch	1899	36	Female	Recent endocarditis	Descending branch of left coronary artery	Sudden
MacCallum	1905	Past middle age	Male	Recent endocarditis	Mouth of left coronary artery	Sudden
Lamb	1913	35	Male	Recent endocarditis	Mouth of left coronary artery	Sudden
Gallavardin and Dufourt	1913	63	Male	Ventricular thrombus	Descending branch of left coronary artery	Gradual
Kaufmann	1922	35	Male	Parietal aortic thrombus	Descending branch of left coronary artery	Sudden

ports reviewed here are apparently not convincing as examples of coronary emboli. Karsner[14] stated that if the occlusion of the coronary artery is due to emboli, a source of the emboli must be indicated. If the source of the embolus is not clearly demonstrable, the case should not be accepted as a proved case of coronary embolism, not only because it is not completely explained but also because the demonstration of the source of the embolus aids materially in differentiation between thrombus

and embolus. This is the more important because the histological differentiation is very difficult and often cannot be made. Only in cases where the vessel wall is healthy is it evident that the lesion in question is an embolus rather than a thrombus.

CASE REPORTS

CASE 1.* *Clinical Findings:* The patient, a thirty-five-year-old male, was admitted to the hospital because of bronchopneumonia. The previous history was irrelevant. On the day after admission it was noted that the pneumonia was spreading and that there was auricular fibrillation. He was given digitalis and put in an oxygen tent. A few days later, the patient was quite restless and complained of pain in the right leg. Subsequently, the leg became cold from the mid-thigh down, dusky, and of a mottled blue color. The right femoral artery showed no pulsation at the inguinal ring. Gradually, the leg became mummified and amputation was advised as soon as the patient's condition improved. About three weeks after the first onset of pain in the right leg, a definite line of demarcation of the gangrene had formed, and, under ethylene anesthesia, the leg was amputated between the middle and lower third of the femur. The popliteal artery and veins were occluded. Just below the knee an abscess was encountered, which was cultured and revealed streptococci and staphylococci. The patient gradually improved after the operation and was in excellent condition. Seventeen days after the operation, without any premonitory symptoms, he died suddenly. The clinical diagnosis was resolving pneumonia; embolus in the right femoral artery, with gangrene of the leg; thrombosis of the right femoral vein, and pulmonary embolism.

Autopsy Findings: The autopsy revealed a well developed but markedly emaciated white male about thirty-five years old. The right limb had been amputated at the junction of the lower and middle thirds of the femur. The pericardial and peritoneal cavities appeared normal. Both pleural cavities, however, were partially obliterated; there were fibrous adhesions which were torn with difficulty. The aorta showed a marked diffuse arteriosclerosis with an atheromatous ulcer very close to the bifurcation. The ulcer was covered by a mural thrombus. The right femoral artery was completely occluded by an embolus. The right external and internal iliac arteries also revealed arteriosclerotic changes. The right femoral vein was completely occluded by a thrombus which extended into the right iliac vein. The heart was enlarged, weighing 400 grams. The right auricle contained an embolus which extended into the right ventricular cavity. The foramen ovale was patent. A small embolus was found in the descending branch of the left coronary artery in an area about 1 cm. from its point of origin. The intima of the coronary arteries was smooth. The remainder of the heart showed no changes. Both lungs were air containing, with the exception of the right lower lobe which was firmer than normal and which on section showed many large areas which were coarsely granular in appearance, dry and gray. There were several minute emboli in the smaller branches of the pulmonary arteries on both sides. The hilus nodes were enlarged. On section, some of them were partially calcified and showed caseous necrosis in their centers. The brain was moderately hyperemic. Multiple sections of the brain showed no pathological changes.

Histological examination of the lung revealed a characteristic organized bronchopneumonia. The smaller and larger arteries in the sections of the lung showed marked arteriosclerosis. The thrombus in the femoral vein and the embolus in the femoral artery proved to be organized. There also was an acute and chronic inflammation around the femoral vein.

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*I am indebted to Dr. George Davenport for the clinical notes.

Summary: This was a case of diffuse arteriosclerosis with mural thrombi in the aorta, from which a piece had broken loose and lodged in the right femoral artery, causing gangrene of the leg. The marked arteriosclerosis of the femoral artery, the pressure of the embolus upon the femoral vein, and also the inflammatory changes close to the vein might have been responsible for the thrombosis of the femoral vein. Pieces of the thrombi had broken loose and formed emboli which lodged in small branches of the pulmonary artery and also in the right auricle, partially extending into the right ventricle. There was a patent foramen ovale through which an embolus must have entered the left heart and lodged in the descending branch of the left coronary artery. The patient died suddenly.

CASE 2.* *Clinical Findings:* The patient, seventy years old, male, was admitted to the hospital because of attacks of pain typical of angina pectoris. The physical examination revealed weak but regular heart sounds. The heart was enlarged on percussion. The liver was also enlarged. A pericardial friction rub was noted. A few days after admission to the hospital, auricular fibrillation developed. The patient gradually improved, but on the sixth day of his hospitalization his pulse suddenly became weak and irregular. Cheyne-Stokes breathing and marked cyanosis developed, and he died within a few minutes. The clinical diagnosis was coronary thrombosis and myocardial infarction.

Autopsy Findings: The body was that of a well developed, slightly emaciated white male about seventy years old. There was a diffuse arteriosclerosis, with marked coronary sclerosis. The heart was hypertrophic and dilated, weighing 635 grams. There was an arteriosclerotic occlusion of the ramus marginis obtusi of the left coronary artery and a recent infarct in the lateroposterior wall of the left ventricle. An acute fibrinous pericarditis was found in the corresponding area of the pericardium. The circumflex branch of the right coronary artery in an area about 1 cm. from its mouth, showed an atheromatous ulcer and a small mural thrombus. In the region where the posterior descending branch comes off from the right circumflex, there was an embolus, about 1 cm. in length, completely occluding the lumen of the right circumflex branch. The autopsy further revealed chronic passive hyperemia of the visceral organs but otherwise no changes of note.

Histological Examination: Sections of the circumflex branch of the right coronary artery which contained the thrombus showed a typical atheromatous ulcer. The thrombus revealed evidence of organization, while the sections which were taken from the region of the embolus showed no attempt toward organization.

Summary: This was a case of marked arteriosclerosis, coronary sclerosis, and coronary thrombosis with myocardial infarction. The thrombus, located in the proximal portion of the circumflex branch of the right coronary artery, showed evidence of organization and did not completely occlude the lumen. To judge from the appearance of the thrombus and also from the history, it is likely that the thrombus was about six days old. A piece of the thrombus had broken loose and formed the embolus which had lodged in the region where the posterior descending branch comes off the right circumflex branch. The patient died suddenly as a result of the coronary embolism.

*I am indebted to Dr. Leon Bloch for the clinical notes.

CASE 3.—This was a private case which was not admitted to the hospital.* The patient, a male seventy-two years old, had a history over a period of seventeen years typical of angina pectoris. He had been under the constant care of a physician during the last six years of life, having more or less constant attacks of angina pectoris and attacks of pain in the legs. After a quiescent period of some duration he again had a sudden severe attack which was diagnosed clinically as coronary thrombosis. He improved, however, and was well for about a year when he had another similar, very severe attack. He recovered, however, but showed signs of congestive heart failure. His heart did not seem to be enlarged. There was a slow but definite improvement. Without warning, however, he died suddenly three weeks after the last attack. The clinical diagnosis was coronary sclerosis and thrombosis, with myocardial infarction, and probable rupture of the heart.

Autopsy Findings: The body was that of a well developed and well nourished white male of about seventy years of age. Both pleural cavities contained a slightly excessive amount of fluid. The pericardial and peritoneal cavities appeared normal. The heart was enlarged, weighing 500 grams. An aneurysm in the apical portion of the left ventricle was found, as well as a diffuse myocardial fibrosis. There was a sclerosis of the coronary arteries and complete occlusion of the descending branch of the left coronary artery by an old, completely organized thrombus. The aorta revealed marked arteriosclerotic changes, with an atheromatous ulcer in the aortic wall of the sinus of Valsalva; the ulcer was covered by a thrombus. The mouth of the right coronary artery, being very close to the atheromatous ulcer, was plugged by a very recent embolus which apparently had arisen from the thrombus covering the atheromatous ulcer. The remainder of the visceral organs showed evidence of chronic passive hyperemia.

Histological examination of the aorta showed a typical atheromatous ulcer covered by an organizing thrombus. The embolus at the mouth of the right coronary artery revealed no evidence of organization.

Summary: This was a case of diffuse arteriosclerosis, with old occlusion of a main branch of the left coronary artery. The embolic occlusion of the mouth of the right coronary artery was responsible for the sudden death.

DISCUSSION

Each of the three cases showed a coronary embolus which had led to sudden death. The sources of the emboli were a venous thrombus (by patent foramen ovale) in the first instance, a mural thrombus in the coronary artery in the second instance, and a small mural thrombus covering an atheromatous ulcer in the sinus of Valsalva in the third instance.

The first case is of interest because of the unusual source of the embolus and the paradoxical embolism. I was able to find only one such case in the literature. This case was reported by Wolff and White.[34] These authors described a forty-three-year-old female with a carcinoma of the ovaries. The pelvic veins were thrombosed. There was a patent foramen ovale, and an embolus was found in the descending branch of the left coronary artery. The authors did not state whether the patient succumbed slowly or whether death occurred suddenly. A somewhat

*I am indebted to Dr. Solomon Strouse for his clinical records.

similar case in which the embolus, however, consisted of tumor cells was described by Thompson and Evans.[29] They found a primary teratoma of the testis in a patient who at autopsy also revealed a patent foramen ovale and a tumor embolus in the left coronary artery. The authors did not state which branch was involved. Emphasis was laid, in their article, upon the mechanism of paradoxical embolism. To favor the establishment of a paradoxical embolism, they believed it essential that over one-third of the pulmonary circulation be depleted by a pulmonary embolism or that the pressure in the right auricle be increased. Wittig[23] maintained that the presence of a thrombus and open foramen ovale is not enough to explain paradoxical embolism. The flow of blood from the right to the left auricle is essential. He believed that an increased pressure in the right auricle as seen in cases of emphysema or pneumonia may be responsible for the passage of blood through the foramen ovale. Our case revealed an organizing bronchopneumonia, multiple emboli in branches of the pulmonary artery, and, also, an embolus in the right auricle, extending partly to the right ventricle. These findings might easily explain an increased pressure in the right auricle and be responsible for the passage of the embolus from the right into the left auricle. It probably is purely accidental that the embolus lodged in the descending branch of the left coronary artery.

It is interesting to note that a single embolus in one branch of the coronary artery has caused sudden death. None of the other coronary branches revealed any changes. This should be emphasized in view of the fact that a complete occlusion of a branch of the coronary artery, either by arteriosclerotic plaques or by a thrombus, does not necessarily lead to sudden death. This patient was thirty-five years old, at which age collaterals of the coronary arteries apparently were not yet established sufficiently (Gross[9]). Also, the fact that the coronary arteries were normal seems to speak against the assumption of a collateral circulation. An embolus in a main branch of the coronary artery, therefore, must have shut off enough of the nutrition of the heart to be responsible for the sudden death.

The second case was typical of coronary sclerosis and thrombosis with myocardial infarction. The patient also had a mural thrombus in the circumflex branch of the right coronary artery which, however, did not completely occlude the lumen. The thrombus must have been present for some time because of its organization. The patient, therefore, could not have died of the thrombus. The death finally occurred suddenly following the embolus which had resulted from the mural thrombus. Emphasis might be laid upon the fact that both the thrombus and the embolus were found in the same branch. This shows how important it is to open the coronary arteries in such cases completely and not to stop the dissection when a thrombus is found in the proximal portion of a coronary artery. The patient died suddenly of coronary embolism.

The abruptness of the death is explained by the additional findings of the marked arteriosclerosis of other branches of the coronary artery and the old myocardial lesions.

Huber,[12] as was mentioned before, described in detail one similar case. He also referred to three other cases but without details.

The third case is very unusual. The sudden death was undoubtedly caused by the embolus which occluded the mouth of the right coronary artery. The left descending branch was plugged by an old thrombus. There are several cases reported in the literature which are somewhat similar to this one. Oestreich[24] reported a thirty-year-old male dying suddenly during his wedding night. There was an arteriosclerotic ulcer covered by a thrombus in the aorta at the site of the sinus of Valsalva. The mural thrombus had occluded the mouth of the right coronary artery. The thrombus also gave rise to an embolus which had lodged in the main stem of the left coronary artery. Chiari[6] described a thrombus which had occluded the main stem of the right coronary artery. There was also a recent embolus in the main stem of the left coronary artery. The thrombus from which the embolus originated apparently occurred on the basis of an atheromatous ulcer in the sinus of Valsalva. Barth[2] referred to a thirty-year-old male who died suddenly. A thrombus had occluded the mouth of the right coronary artery. The thrombus occurred on the basis of an atheromatous ulcer of the aorta situated close to the opening of the right coronary artery.

The sudden death in the last case is easily explained in view of the fact that there was also an old thrombus in the descending branch of the left coronary artery. The recent embolus which had occluded the mouth of the right coronary artery, took its origin, as in the three last mentioned reports, from an atheromatous ulcer in the ascending aorta.

Why the coronary arteries are so rarely the seat of true embolism is very difficult to explain. Marie[22] believed that the marked difference of the calibers of the aorta and the coronary arteries is in part responsible for the rarity of coronary embolism. Powell[25] stated that the situation of the coronary vessels at the commencement of the aorta, the right angle at which they leave the vessel and the bulk and impetuosity of the blood current at this portion are all conditions unfavorable to the passage of a clot into these small sized arteries. This opinion is also shared by Benson.[3] If the right angled departure of the coronary arteries were the only reason for the rarity of coronary embolus, this might explain why emboli do not more frequently lodge in the coronary vessels, but would not explain why the mouth of the coronary artery is not more frequently involved in embolism. The various eddies at the mouths of the coronary arteries as produced by systole and diastole, and also the peculiar flow into the coronary vessels during systole and diastole might explain the rare involvement by emboli of the mouths of the coronary arteries and of the vessels themselves.

SUMMARY

The literature on coronary embolism is reviewed and the rarity of such an occurrence emphasized. Cases in which the source of the embolism is not found at autopsy should not be accepted as proved cases of coronary embolism. Three cases of coronary embolism are reported. In one, the source of the embolus was a thrombus in the femoral vein; there was also a patent foramen ovale. In the second case, the source of the embolus was a mural thrombus in the right coronary artery, occurring on the basis of an atheromatous ulcer. The embolus had lodged in the distal part of this artery at the origin of the posterior descending branch. In the third instance, the source of the embolus which had occluded the mouth of the right coronary artery was a thrombus occurring on an atheromatous ulcer in the region of the sinus of Valsalva. In all three instances the patients died suddenly.

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OBSERVATIONS ON ARTERIAL BLOOD PRESSURE DURING ATTACKS OF ANGINA PECTORIS*

SAMUEL A. LEVINE, M.D., AND A. CARLTON ERNSTENE, M.D.
BOSTON, MASS.

THE character, intensity and distribution of the pain of angina pectoris have long been a matter of clinical study and speculation. At present, however, the phenomena taking place during the actual anginal attacks are being investigated in greater detail. Changes in the electrocardiogram have been noted during spontaneous attacks of angina pectoris,[1, 2, 3] and during attacks produced by epinephrine[4] or by deliberate effort.[5] Frequent reference has also been made by many writers to changes in blood pressure during such attacks. Curiously enough, although such statements are very common, data concerning the blood pressure during anginal spells are very meager. The statement is frequently seen that the blood pressure during attacks is variable, that it may be unchanged or be lowered or increased. Such are the views expressed by Keefer and Resnik[6] and by Sutton and Lueth.[7] It is noticeable that, with few exceptions, the cases that are published in detail show a higher level of blood pressure during pain than when the attack has subsided. The four cases reported by Lewis[8] and the eight by Burgess[9] all showed higher levels of blood pressure during spontaneous attacks of angina than those found in the same patients when free from pain. Only two of the thirty patients studied by Wood and Wolferth[5] showed a fall in blood pressure during attacks of angina. Allbutt[10] also mentions a similar case with a fall in blood pressure. It is the purpose of this study to record additional observations on the blood pressure during attacks of angina pectoris and to urge others to make similar notations.

The opportunities to make examinations of the blood pressure during attacks of angina are neither numerous nor conducive to prolonged study. The physician under such circumstances feels the need to bring the attack to an end and necessarily uses medication which of itself diminishes the blood pressure. It is therefore more difficult to draw the proper conclusions concerning the blood pressure changes than it would be if we dared to await the spontaneous disappearance of the attacks. There is much of an inferential character, however, to be obtained from these experiences. We have had the opportunity during the past decade or so to obtain readings of the blood pressure during spontaneous attacks of anginal pain in twenty-three patients (Table I). Of the accuracy of the diagnosis in these cases there is very little doubt. No attempt has been made to correlate the time of disappearance of the

*From the Medical Department of the Beth Israel Hospital and the Department of Medicine, Harvard Medical School, Boston.

pain and the change in blood pressure. This has been done in small groups of patients by Lewis[8] and Burgess.[9] In seven of our patients, the level of the blood pressure preceding the attack was known. In some of these, the readings were actually obtained a few minutes before the attack. In most of the cases, the attack was brought to an end by the use of nitroglycerin. In three, however, the pain was allowed to subside spontaneously, and blood pressure measurements were therefore obtained

TABLE I

OBSERVATIONS ON ARTERIAL BLOOD PRESSURE IN SUBJECTS WITH ANGINA PECTORIS

SUBJECT	SEX	AGE	ARTERIAL BLOOD PRESSURE					NITROGLYCERIN ADMINISTERED
			BEFORE ATTACK		DURING ATTACK	AFTER ATTACK		
			READING	INTERVAL BEFORE PAIN		READING	INTERVAL AFTER PAIN	
		YEARS	MM. HG		MM. HG	MM. HG	MINUTES	
R. B.	F	33	140/90	Few minutes	180/20	140/90	6	Yes
A. R.	F	50	110/70	Few minutes	164/94	132/88	6	Yes
R. W.	F	65			170/85	155/85	3	Yes
M. W.	M	53			138/82	98/76	11	Yes
S. S.	F	60			240/140	210/120	4	Yes
M. S.	M	62			190/90	170/85	3	Yes
H. R.	M	56			172/110	154/95	5	Yes
L. H.	F	64	160/90	10 minutes ±	230/140	165/95	6	Yes
J. G.	M	50			154/90	96/40	10	Yes
M. G.	M	62			196/110	152/90	4	No
S. C.	M	54			230/120	204/108	5	No
M. L.	M	68			210/110	130/80	300	Yes
M. H.	M	68			215/130	150/100	3	Yes
T. G.	M	62			210/110	140/80		
S. F.	M	45			140/80	108/78	3	Yes
F. B.	M	60			160/108	115/75	15	Yes
H. B.	M	68			210/145	195/120	5	Yes
P. A.	M	62	140/100	10 minutes ±	200/102	126/92	10	Yes
M. C.	F	65	170-190 / 70 70	During previous months	210/94	190/90	4	Yes
A. G.*	M	31			165/90	140/90	4	Yes
B. P.†	M	70			204/80	168/64	10	Yes
E. C.‡	F	28	112/80	Few minutes	148/98	114/90	5	No
F. R.‡	M	15	130-140 / 50 40	Few hours	210/90	140/50	60	Yes

*Had thyrotoxicosis in addition to angina pectoris.
†Had syphilitic aortic insufficiency in addition to angina pectoris.
‡Had rheumatic aortic stenosis and insufficiency in addtion to angina pectoris.

uninfluenced by the use of vasodilator drugs. In not a single instance did the blood pressure level fail to be higher during pain than after the pain had subsided, or than before the attack had started in those instances where earlier readings were available.

The obvious criticism may be raised that the blood pressure would have to be lowered after the use of vasodilator drugs. In seven of the patients, however, it was known that the level to which the pressure returned was the one customarily found in that same patient when free from pain. It is most significant that in no instance was the pressure

during anginal pain lower than at other times. This point deserves particular attention in the light of the statement frequently made in medical writings that the blood pressure may fall during anginal attacks.[11, 12] We believe that such an occurrence must be very rare. When a fall in blood pressure takes place, one may reasonably suspect either that an attack of coronary thrombosis is occurring or that the pain is not anginal in character. A reconsideration of four cases published by one of us[12] ten years ago well illustrates the difficulties in this problem. Of these four cases, the one which showed a fall in blood pressure undoubtedly had a coronary occlusion. A review of all the clinical data in this case (fever, leucocytosis, pulmonary edema and sudden death) in the light of our present knowledge makes this diagnosis certain. Another patient with no change in blood pressure had apical pain accompanying hypertension and only developed the typical substernal pain of angina pectoris some years later. The remaining two showed the customary rise in blood pressure during attacks.

The question may readily be asked whether the pain of angina pectoris does not of itself produce the elevation in blood pressure. We have had the unusual opportunity of observing a patient with angina pectoris during two different attacks of severe renal colic. Two hypodermic injections of 15 mg. of morphine were required to bring relief in both these attacks. During the height of the pain there was no anginal discomfort and the blood pressure remained unchanged. Numerous readings during the course of nine years were available in this case. The systolic pressure ranged between 120 and 140 mm. Hg, and the diastolic pressure between 70 and 80 mm. Hg. At the height of the pain from renal colic on one occasion the readings were 140 mm. Hg systolic and 80 mm. Hg diastolic with a pulse rate of 68 per minute; and on the other occasion they were 120 mm. Hg systolic and 80 mm. Hg diastolic with a pulse rate of 62 per minute. We cannot therefore accept the contention that the pain of angina pectoris is the cause of the elevation in blood pressure. On the other hand, the almost constant association of rise in blood pressure with anginal pain makes one suspect that the two are related. Both may be concomitant results of a third unknown influence or the elevation in pressure may actually produce the pain. The fact that in the subsidence of the attack, pressure levels need not go hand in hand with the disappearance of pain[8, 9] does not dismiss the possibility that the onset of the attack was actually produced by the increased pressure. It would be interesting and important to ascertain whether attacks can be precipitated by other methods of elevating pressure and whether the induction of attacks can be inhibited by preventing a rise in pressure.

SUMMARY

Blood pressure readings were obtained during spontaneous attacks of angina pectoris in twenty-three patients. In seven, the previous blood

pressure readings were known. In three, the attacks were allowed to end spontaneously, and in twenty relief was obtained by administering nitroglycerin.

In every instance the level of the systolic pressure was distinctly higher during pain than when the patient was free from pain. Although this may not be an invariable relationship, this study and a survey of the cases recently reported leads one to the conclusion that a failure of the blood pressure to rise in anginal attacks is rare.

Evidence is presented to show that in patients with angina pectoris, pain alone, e. g., that of renal colic, neither produces an elevation in blood pressure nor brings on an attack of angina.

Although we suspect that a temporary elevation in blood pressure is an important factor in the production of anginal attacks and may even be a necessary immediate cause of the attack, a final decision as to this relationship will require further investigation.

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THE OCCURRENCE OF HEART-BLOCK IN CORONARY ARTERY THROMBOSIS*

DAVID BALL, M.D.
NEW YORK, N. Y.

THE occurrence of heart-block during the course of an acute coronary artery thrombosis is rare. The case to be reported, which has been studied in great detail with frequent serial electrocardiograms, revealed an early complete heart-block, which in a retrograde fashion went through the stages of partial heart-block, gradually returning to normal sinus rhythm, with complete recovery.

Acute coronary artery thrombosis usually occurs in individuals with a normal cardiac rhythm and in the majority of cases the rhythm remains regular. However, various arrhythmias can occur with the onset, and during the early stages of an acute coronary closure. The frequency with which disturbances in rhythm may be detected will depend largely upon how often the patient is examined, since many of the irregularities are transient and often cause few if any symptoms.

Premature contractions, both ventricular and auricular, are observed during the early stages of an attack and are of little or no significance. Paroxysmal auricular fibrillation occurs more frequently. Levine[1] observed it in 34 instances of his series of 145 cases. He did not find that this arrhythmia materially altered the prognosis of the case. Occasionally permanent auricular fibrillation remains. Auricular flutter is rarely seen, and in one case personally observed, the patient recovered. A more uncommon but important disturbance in rhythm is the development of paroxysmal ventricular tachycardia. This condition has been well described by Herrmann,[2] Robinson,[3] and Levine,[4] and Levine, Stevens, and Fulton.[5] The prompt recognition of this disturbance and institution of proper therapy may prove life saving.

Complete A-V dissociation during an attack of acute coronary artery thrombosis can occur and has been observed. Levine[1] observed it only twice in his series of 145 cases, an incidence of 1.37 per cent. Both cases proved fatal. One of the earliest reports of transient complete heart-block in coronary thrombosis with recovery was that of Frothingham[6] in 1927.

The presence of complete heart-block during the early stage of a coronary closure has not been adequately explained. A careful study of the case to be reported together with an analysis of the cases of heart-block in coronary thrombosis described in the literature furnishes a key to the explanation for its occurrence.

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*From the Medical Service of Dr. A. A. Epstein, Beth Israel Hospital, New York.

While heart-block in coronary closure is uncommon, it is even more rare to observe all of its stages in one individual in whom recovery has taken place. The report of such a condition with frequent serial electrocardiograms is presented.

CASE REPORT

A. S., B. I. H. No. 44517, male, aged forty-six years, walked into the out-patient department of the Beth Israel Hospital, and presented the following history: Two days previously, while walking home from work, he suddenly experienced a burning sensation in the region of the lower sternum and epigastrium. He continued to walk and when he reached his home he vomited profusely and broke out into a cold

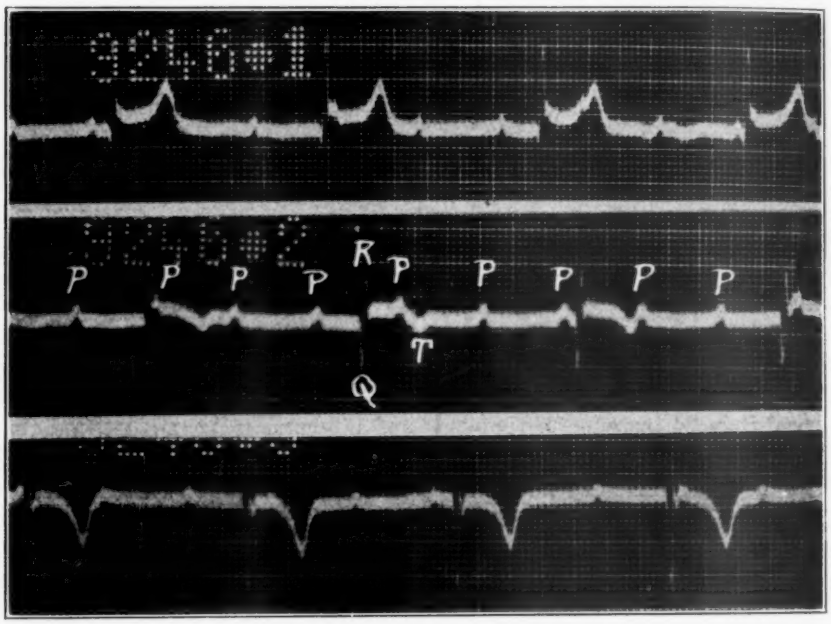

Fig. 1.—Electrocardiogram taken first day, about forty-eight hours after onset of attack. Complete auriculoventricular dissociation. Auricular rate 117, ventricular rate 45 per minute. T_2 slightly inverted. T_3 deeply inverted with cove-plane shape. Deep Q-waves in Leads II and III.

sweat. He slept poorly that night because of pain and burning in the epigastrium which was almost constant. There was difficulty in breathing. The pain was intensified when he was lying on the left side, and he perspired profusely during the night. He remained at home the next day and complained of intermittent burning and pain in the epigastrium and lower chest, which continued through the night but was less severe than the night before. He then walked about one mile from his home to the clinic. The pain became worse on walking, and for the first time it was felt in the region of the left shoulder. Physical examination revealed signs of an extensive pericarditis. The heart rate was 72 per minute and there were occasional premature beats. He was immediately sent into the hospital. He protested and maintained that he had only "stomach trouble" and did not require hospitalization. When examined in the ward, he showed the following: Temperature 100.2°, pulse 50, respiration 24. He was sitting up in bed and did not appear acutely ill.

He was only slightly dyspneic and perspired moderately. There was slight cyanosis of the lips, and he complained only of very slight pain behind the lower sternum. Pressure over the styloid process (Libman's test) indicated an individual who was markedly hyposensitive to pain stimuli. The apex beat was not visible nor palpable, but the heart was slightly enlarged to the left on percussion. The rhythm was regular and the rate 50 per minute. A typical loud, leathery to-and-fro pericardial friction rub was heard over almost the entire precordial area. The first heart sound was impure and at times was heard with a varying degree of intensity due to the varying time relationship between auricular and ventricular contraction as occurs in complete heart-block. A third sound, distinctly grating in quality, was constantly heard in about the middle of each long diastolic pause. It was at first thought that it was either an auricular or a pericardial sound. The final impression was that

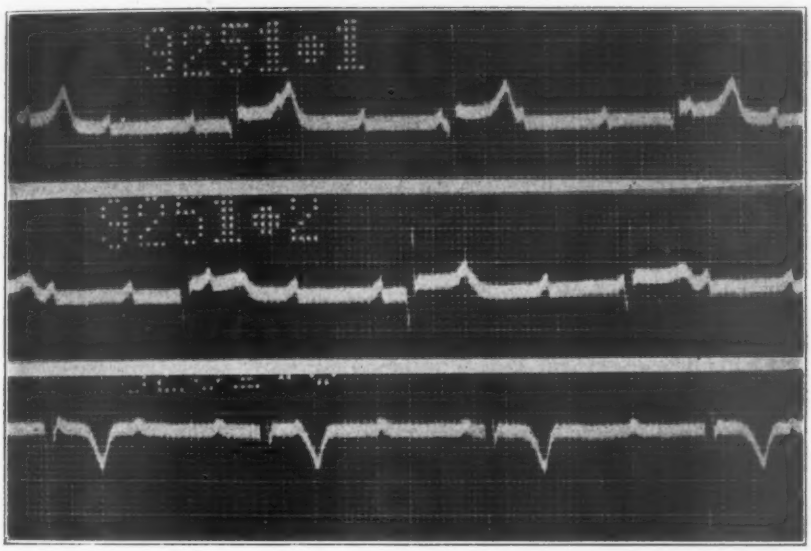

Fig. 2.—Third day. Complete A-V dissociation. Elevated R-T segment in Leads I and II. Deep Q_2 and Q_3. T_3 inverted and cove-plane.

this peculiar sound was of pericardial origin, produced by the visceral and parietal layers of the pericardium coming in contact during the diastolic "ballooning" out of the ventricles. This peculiar sound was heard only during the period of complete heart-block. The lower edge of the liver was 5 cm. below the costal margin. The history and the peculiar clinical findings suggested the diagnosis of acute coronary artery occlusion, probably involving the right coronary artery, with complete A-V dissociation. The clinical diagnosis of right coronary artery occlusion was made because of the enlargement of the liver and the associated heart-block. Electrocardiograms (Figs. 1 and 2), the first of which was taken approximately forty-eight hours after the onset of the attack, confirmed the clinical diagnosis and showed a complete A-V dissociation with evidence of acute myocardial injury. There was elevation of the R-T segment in Leads I and II and deep cove-plane inversion of the T waves in Lead III.

During the first two days in the hospital he complained only of slight retrosternal pain and was given morphine sulphate, grains ¼ (0.015 gm.) three times. He was remarkably free of symptoms during the remainder of his hospital stay of fifty-eight days. The temperature which on admission was 100.2°, rose to 102° on the

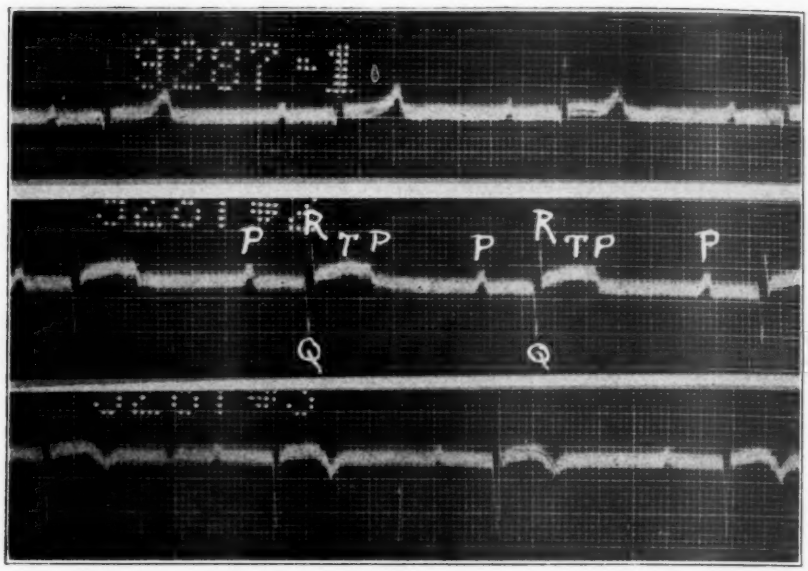

Fig. 3.—Seventh day. Two-to-one block. R-T segment Lead I almost isoelectric. T_3 less inverted.

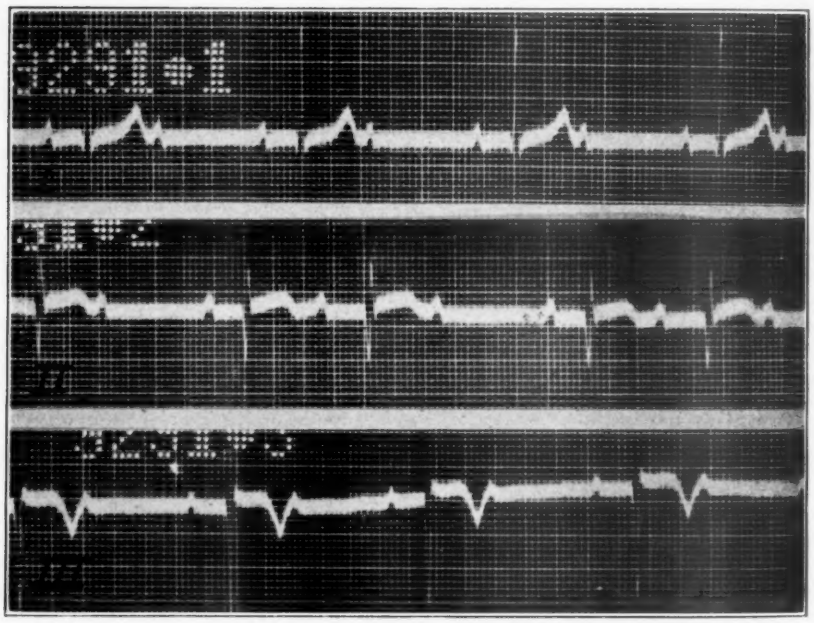

Fig. 4.—Eighth day. Two-to-one block in Lead I. Varying two-to-one and one-to-one conduction in Lead II. Two-to-one block in Lead III.

second day and gradually declined, becoming normal on the sixth day. The white blood count on admission was 16,050 with 82 per cent polynuclear leucocytes. The sedimentation rate was 42 per cent (normal 3 to 10 per cent). The leucocytosis persisted for three weeks and the sedimentation rate became normal (5 per cent) on the twenty-seventh day. The blood pressure varied between 92 and 136 mm. of mercury systolic, and 68 to 90 mm. diastolic. The blood Wassermann and urine examinations were negative. The liver, which was at first enlarged, gradually receded and could no longer be felt after the seventh day. The complete heart-block lasted for six days. During this period, the ventricular rate (electrocardiographically) varied between 45 and 60 per minute. Clinically, the heart rate dropped as low as 42 per minute. On the seventh day, the electrocardiogram (Fig. 3) showed a two-to-one heart-block with a ventricular rate of 53 per minute, and because of this

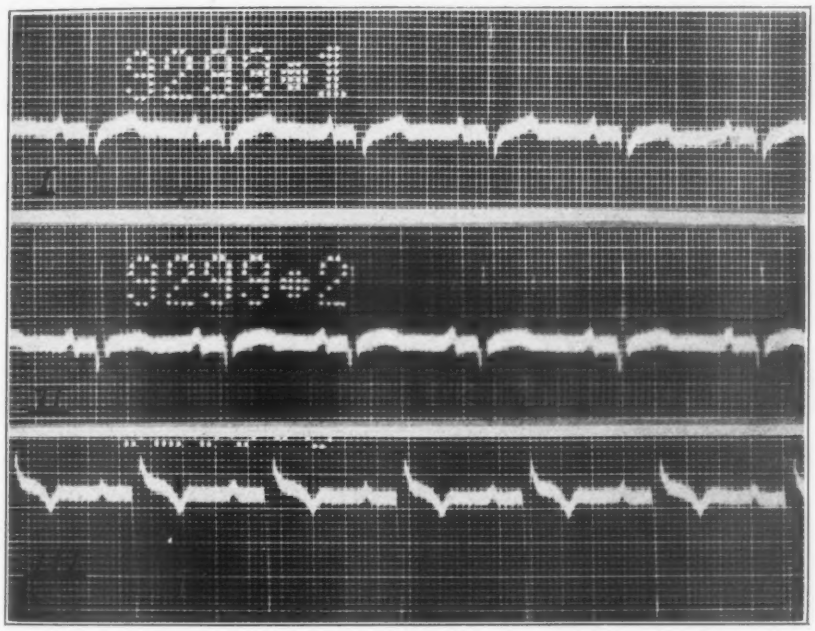

Fig. 5.—Ninth day. Normal sinus rhythm. P-R interval measures 0.22 sec.

a return to normal sinus rhythm was anticipated. The next day (eighth day) the cardiac rhythm was irregular. The electrocardiogram (Fig. 4) showed an arrhythmia due to a varying two-to-one block and one-to-one A-V conduction. The rhythm became regular the next day (ninth day). Electrocardiogram (Fig. 5) showed a normal sinus rhythm with a rate of 82 per minute. The P-R interval measured 0.22 second, the last remaining evidence of the heart-block. On the next day (tenth day) the electrocardiogram showed a normal P-R interval and normal sinus rhythm remained permanently established. The pericardial friction rub was heard distinctly for fifteen days.

Figs. 6 and 7 show single complexes of serial electrocardiograms taken from the day of admission until six months later. They show at first the elevated R-T segment in Leads I and II and deep cove-plane inversion of T_3. The R-T interval in Leads I and II gradually became isoelectric with inversion of the T-waves in Lead II and lesser inversion of T_3. The T-waves in Lead I

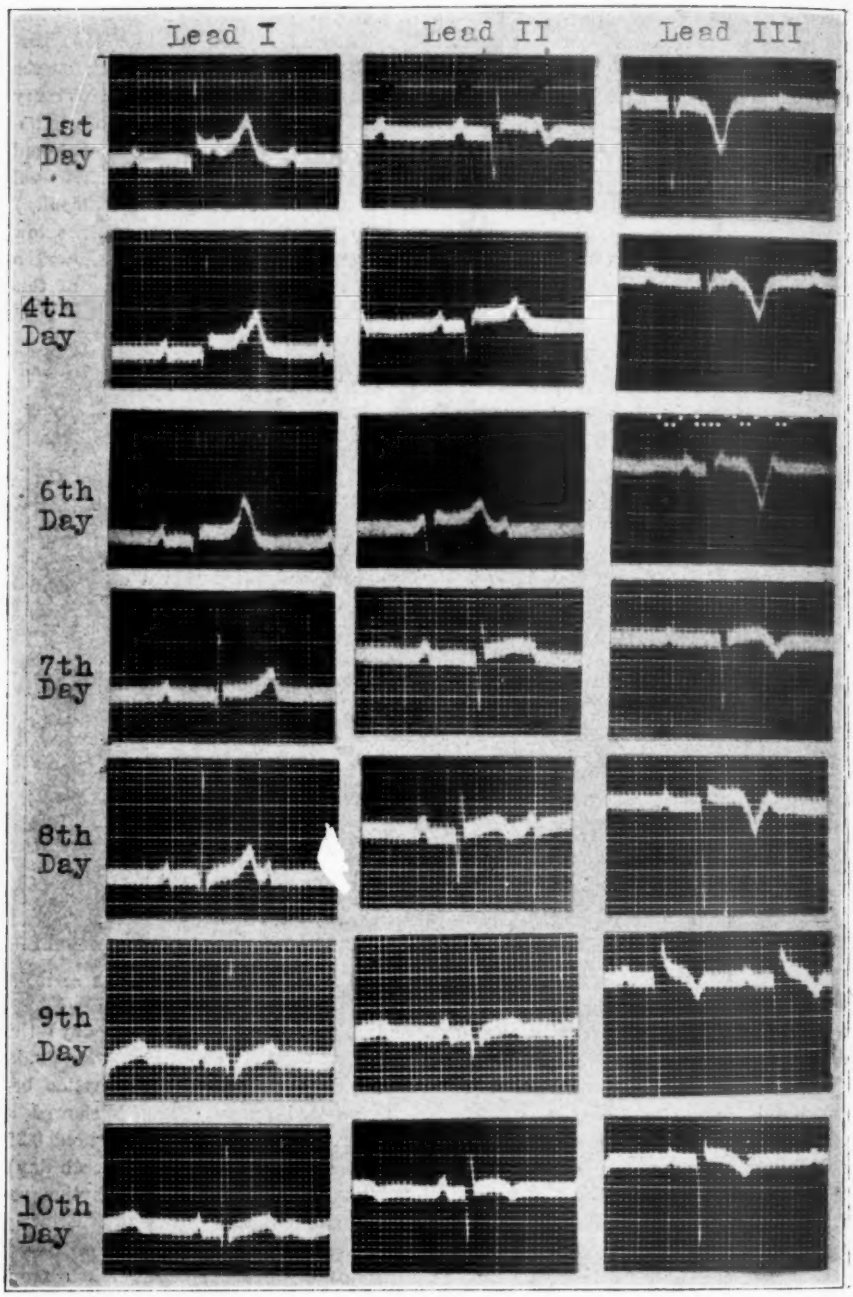

Fig. 6.—Serial electrocardiograms of single complexes from the three conventional leads from first to tenth day, showing successive electrocardiographic changes following coronary occlusion.

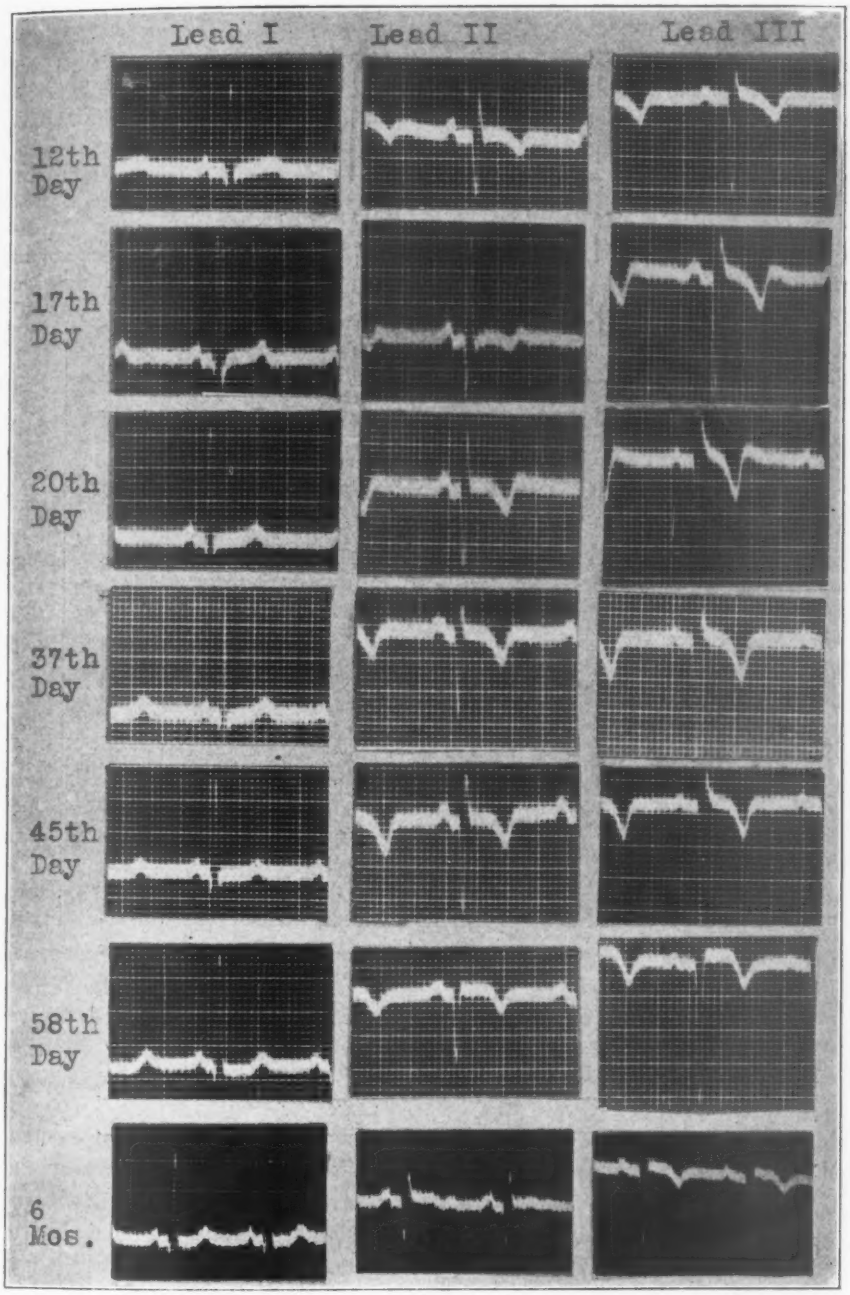

Fig. 7.—Serial electrocardiograms of single complexes from the three conventional leads from twelfth day to six months, showing successive electrocardiographic changes following coronary occlusion.

never became inverted. All of the electrocardiograms showed deep Q-waves in Leads II and III. The teleroentgenogram showed slight enlargement of the left ventricle. After the patient was discharged from the hospital he was not seen for five months. He then stated that for the preceding four months he had been working daily pressing shirts eight to nine hours a day, and felt perfectly well. Blood pressure was 180/110 mm. The heart was slightly enlarged to the left. The rhythm was regular and the rate 80 per minute. The heart sounds at the apex were of good quality, and the second aortic sound was moderately accentuated. Both lungs were clear and the liver was not palpable. The electrocardiogram (Fig. 8) now showed very little evidence of previous cardiac damage. It is significant to note that the Q-waves in Leads II and III were still deep. On the basis of the enlargement of the left ventricle and elevated blood pressure, it is assumed that this patient had a

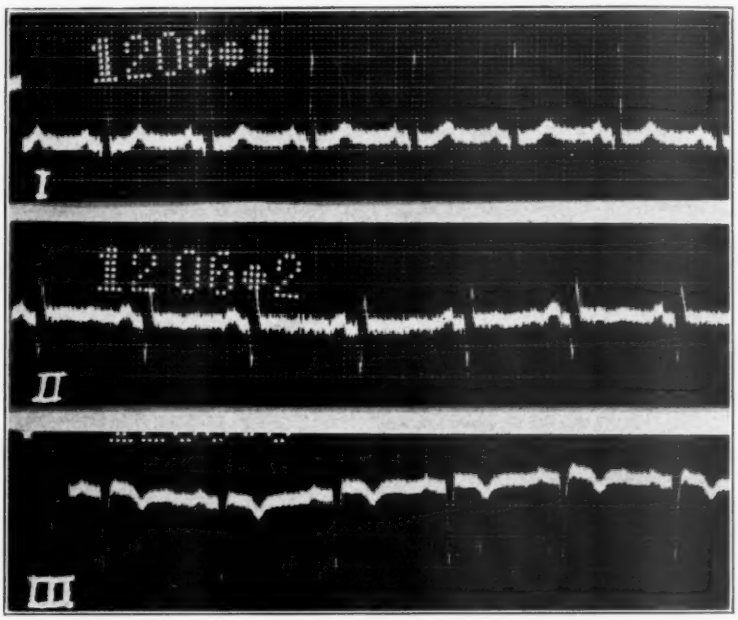

Fig. 8.—Electrocardiogram taken six months after the acute attack. Q_2 and Q_3 are still deeply inverted. T_2 slightly upright and T_3 inverted.

hypertension for some time and the first evidence of vascular disease was the occurrence of an acute coronary artery occlusion.

DISCUSSION

In many cases of coronary artery thrombosis one can, from the electrocardiograms, determine whether the occlusion involves the left or the right coronary artery, as was first shown by Parkinson and Bedford[7] in 1928. They carefully described the successive changes in the electrocardiogram following cardiac infarction and divided the curves into two main groups: type T_1 and type T_3. A definite sequence of changes in the R-T segment and T-waves occurs. The initial change is an elevation of the R-T segment from the isoelectric level followed later by an inversion of the T-waves in Lead I or III, but never in both, and a lesser

degree of inversion in Lead II. Curves taken a few weeks after the acute injury usually conform to one of the two main types, as evidenced by the T-wave inversions. Thus, inversion of the T-waves in Leads I and II occurs in type T_1, indicating an occlusion of the left coronary artery, and conversely inversion of the T-waves in Leads II and III is found where the thrombosis involves the right coronary artery. The T-waves can subsequently return to a complete normal. Often an inverted T-wave in Lead III may be the only residual evidence of a previous infarction. This, plus the deep Q-waves in Leads II and III, is present in the case reported. Barnes and Whitten[8] in a study of the correlation of the electrocardiographic changes, the artery occluded and the resultant area of infarction, confirmed the above findings. Wilson and his co-workers[9] recently reported a study of the electrocardiograms in 56 cases of coronary thrombosis on 17 of which a postmortem examination of the heart was made. Their findings were in complete agreement with those of Barnes and Whitten. In the autopsied cases, curves showing inversion of the T-waves in Leads II and III were always associated with infarction of the area usually supplied by the right coronary artery.

Crawford and his coworkers[10] recently substantiated the findings of Barnes and Whitten by cauterizing definite areas of the heart muscle in cats. They produced typical type T_1 and T_3 changes in the electrocardiogram.

According to these criteria, the case reported here would fall into type T_3, indicating an occlusion of the right coronary artery with resultant myocardial infarction. Although the R-T segment was elevated above the isoelectric level in Lead I in the beginning, the T-waves in Lead I never became inverted. The deep cove-plane inversion of T_3 at the onset, gradually becoming less inverted, and the subsequent development of inverted T-waves in Lead II (Figs. 6 and 7) place these curves in type T_3.

Transient heart-block in coronary artery occlusion is probably due to a disturbance of the circulation to the auriculoventricular node. The A-V node receives its blood supply from the right coronary artery in 92 per cent of the cases and from the left coronary artery in 8 per cent of the cases, depending upon which vessel crosses the "crux" of the heart posteriorly. Thus it would seem that heart-block should be more common when the occlusion occurs in the right coronary artery. This premise is borne out in the following analysis of cases of heart-block with coronary artery occlusion reported in the literature, together with the case presented.

As early as 1913, Oppenheimer and Williams[11] described a case of prolonged incomplete heart-block without a lesion of the bundle of His. At autopsy the posterior descending branch of the right coronary artery was found completely obstructed about 0.5 cm. from its origin as well as the descending and circumflex branches of the left coronary artery.

Histological study revealed sclerosis and marked stenosis of the artery to the A-V node. Serial sections of the bundle of His did not disclose any lesion to explain the block. They stated in conclusion that "complete heart-block without anatomic lesions in the A-V system may possibly be of neurogenic or of circulatory origin, or it may be ascribed to chemical agents, to asphyxia, or to some hindrance to the passage of impulses from the terminal arborizations of the conduction system to the ventricular musculature." Later in discussing a paper by Kugel, Oppenheimer stated that since the original observation, he had had several instances in which it seemed probable that the heart-block was due to circulatory disturbance.

Parkinson and Bedford[7] observed one case of transient heart-block in their series of cases. The electrocardiograms of this case conformed to the typical type T_3.

Hansen[12] reported a case of complete A-V dissociation occurring on the fifth day during an acute attack of coronary artery occlusion with death a few days later. The electrocardiograms were of type T_3 with a deep Q_3. Postmortem examination was not obtained.

Sanders[13] observed a fatal case of coronary artery thrombosis with complete heart-block and a relative ventricular tachycardia. The auricular rate was 120 and the ventricular rate 70 per minute. Electrocardiograms were of the type T_3. On postmortem examination, a thrombus was found obstructing the right coronary artery with an infarction involving the greater portion of the outer wall of the right ventricle extending to the apex and to the anterior and posterior portions of the interventricular septum.

Dr. M. A. Rothschild[14] has kindly furnished me with a remarkable case from his private practice. This was a man of fifty-three years who had a severe attack of precordial pain and dyspnea while riding horseback. Clinically he had suffered an attack of acute coronary artery thrombosis. The electrocardiogram showed a complete A-V dissociation with inversion of the T-waves in Leads II and III, typical type T_3. The heart-block soon disappeared and the electrocardiogram subsequently became entirely normal. Four years later he developed a second attack of coronary artery thrombosis without heart-block and died. The electrocardiogram at this time was of the type T_1. This case is very important since it furnishes an interesting experiment in the same individual. The clinical and electrocardiographic evidence during the first attack would indicate that at this time he had a thrombosis of the right coronary with heart-block, while his fatal attack was electrocardiographically a left coronary occlusion without heart-block.

Frothingham[6] observed transient complete heart-block in a case of typical coronary closure with complete recovery. In his case also, the P-R interval was prolonged when normal sinus rhythm first appeared. The electrocardiograms conformed to type T_3.

Salley[15] observed a case of coronary closure with ventricular tachycardia at the onset which could not be abolished by quinidine. The injection of atropine uncovered a complete heart-block. Electrocardiograms were of the type T_3.

Bell and Pardee[16] reported a case of coronary thrombosis with complete heart-block and recovery. The heart-block lasted eight days during which period there were numerous Stokes-Adams seizures. The electrocardiograms showed classical early and late changes with the development of inverted T-waves in Leads II and III, typical type T_3. They believed that the sudden A-V dissociation with an eventual return to normal rhythm was due to an edema of the tissues which was later absorbed.

Schwartz[17] observed four patients in whom complete heart-block developed during an acute coronary artery closure. Two of the patients died and two recovered. Stokes-Adams seizures occurred in two of the cases, one of which proved fatal. Auricular fibrillation appeared in one instance before normal sinus rhythm was established. The electrocardiograms in all four cases revealed typical type T_3 changes.

Boas[18] observed a woman of fifty-nine years who developed complete heart-block about five hours after the onset of an acute coronary artery thrombosis. The patient died in less than twenty-four hours. No autopsy was obtained. The electrocardiogram showed complete A-V dissociation with inversion of the T-waves in Leads II and III, typical type T_3.

Complete heart-block has been described in sixteen cases of acute coronary artery thrombosis (Table I). Electrocardiographic tracings were obtained in fourteen of the cases, thirteen of which conformed to type T_3 indicating occlusion of the right coronary artery and the remaining case conformed to type T_1 indicating occlusion of the left coronary artery, as was found at autopsy. Confirmation by autopsy was made in three cases; in two a thrombus was found occluding the right coronary artery and in one the left. The electrocardiographic changes as to type and the anatomical findings were in complete agreement in the autopsied cases.

The high frequency of heart-block in thrombosis of the right coronary artery focuses our attention to the course of this vessel and its branches, especially the branch supplying the A-V node. The A-V node is supplied by an artery known as the ramus septi fibrosi, which arises from the right coronary artery in 92 per cent of human hearts, and from the left coronary artery in 8 per cent. This vessel furnishes the chief blood supply to the A-V node. However, important anastomoses occur in this area. Kugel[19] in 1927 called attention to an important anastomotic vessel in the auricle of the human heart. He later described this vessel in greater detail.[20] This artery, known as the arteria anastomotica auricularis magna, is a large anastomotic vessel which arises from the

left coronary artery and is constant in occurrence and site. It was found in all of the fifty normal hearts which Kugel studied. Like the main coronary arteries and their branches, it is subject to variations which fall into three groups.

1. It forms a simple direct anastomosis between the left circumflex coronary artery or its branches and the posterior portion of the right circumflex coronary artery or its branches in the region of the A-V node. This is the most common variation, occurring in 33 of the 50 hearts examined. In this common arrangement it anastomoses freely with the main artery supplying the A-V node.

TABLE I

ELECTROCARDIOGRAPHIC EVIDENCE AND AUTOPSY FINDINGS IN CASES OF CORONARY OCCLUSION WITH HEART-BLOCK

AUTHOR OF CASE	TYPE ELECTROCARDIOGRAPHIC CHANGES	AUTOPSY FINDINGS
1. Ball	T_3	Not done
2. Parkinson & Bedford	T_3	Not done
3. Hansen	T_3	Not done
4. Rothschild	T_3	Not done
5. Frothingham	T_3	Not done
6. Salley	T_3	Not done
7. Schwartz	T_3	Not done
8. Schwartz	T_3	Not done
9. Schwartz	T_3	Not done
10. Schwartz	T_3	Not done
11. Bell & Pardee	T_3	Not done
12. Boas	T_3	Not done
13. Sanders	T_3	Occlusion of right coronary artery
14. Levine	T_1	Occlusion ant. desc. branch left cor. art.
15. Oppenheimer & Williams	Not done	Occlusion of right coronary artery
16. Levine	Not done	Not done

Type T_3 is associated with inversion of the T-waves in Leads II and III, indicating right coronary artery occlusion.
Type T_1 is associated with inversion of the T-waves in Leads I and II, indicating left coronary artery occlusion.

2. It forms a simple anastomosis between the left circumflex coronary artery or its branches and the anterior portion of the right coronary artery or its branches.

3. In the greater part of its course, the vessel is represented by diffuse anastomoses between branches from the anterior portions of the left and right coronary arteries and the posterior portion of the left circumflex coronary artery.

This artery thus serves as a wide anastomotic channel between the right and left coronary arteries in the region of the A-V node. In several of the hearts which were the seat of arteriosclerotic coronary artery disease, this vessel was of unusually large caliber.

We can therefore assume that where the anastomotic artery of Kugel forms a rich, collateral blood supply to the region of the A-V node as in Group 1, heart-block either is not likely to occur or may be very transient, when the right coronary artery is occluded proximal to the branch supplying the A-V node.

However, where the collateral blood supply to the A-V node is not very rich as in the third group variation, heart-block is probably more liable to occur. In this case, occlusion of the right coronary artery, proximal to the ramus septi fibrosi, would temporarily cut off the main blood supply to the node and cause sufficient ischemia to prevent some or all of the stimuli from the auricles from passing through the A-V node and into the bundle of His. Partial or complete A-V dissociation with a supraventricular type of ventricular complex would then result. The impulses producing the idioventricular rhythm arise either in the lowermost portion of the node or in the upper part of the main stem of the bundle of His. This is illustrated by the fact that in all of the electrocardiographic tracings obtained in the reported cases of heart-block in coronary artery thrombosis, the ventricular complexes are always of the supraventricular type. If the patient survives the initial shock and goes on to recovery, the collateral blood supply to the A-V node, mainly through the anastomotic artery of Kugel probably comes into play and gradually supplies sufficient blood to the region of the A-V node so that it again assumes its normal physiological function.

Géraudel[21] has furnished anatomical evidence in support of the above explanation. He demonstrated that stenosis and partial occlusion of the artery supplying the A-V node probably explained the occurrence of partial and complete heart-block in cases where a lesion of the bundle of His or its branches could not be found. By means of serial sections, he carefully examined the entire conduction system and the circulation to the A-V node in three cases of partial and complete A-V dissociation. The A-V node, bundle of His, and its branches were entirely free from any demonstrable lesion or injury in all three instances. However, a study of the artery supplying the A-V node revealed singular findings. In one case the nodal vessel arose from the left coronary artery and was almost completely obstructed by a zone of proliferative endarteritis. In the remaining two cases the artery to the A-V node arose from the right coronary, and in both instances the vessel showed marked narrowing with almost complete obliteration just above its point of origin. It may be significant that in all three cases the stenosing lesion in the nodal artery was found just at or proximal to its point of origin from the main coronary artery. In the first case the left coronary artery crossed the "crux" of the heart and supplied the artery to the A-V node, whereas in the other two cases in which the nodal artery arose from the right coronary artery, this main vessel was found to cross the "crux." This is in accord with the studies of Gross.[22]

Jellick, Cooper, and Ophuls,[23] in 1906, described a case of Stokes-Adams syndrome occurring fourteen days before death in an individual suffering from acute epididymitis and septicemia. "Postmortem examination of the heart demonstrated anemic necrosis of the muscular septum in the region of the bundle of His consequent on a recent thrombosis of its nutrient arteries."

Neuhof[24] described a case of complete heart-block and auricular fibrillation in a woman of eighty-three years who died in heart failure. At autopsy the coronary artery was found thickened and sclerosed although slightly patulous (he does not state which coronary) and the artery supplying the A-V node was completely calcified.

Carter and McEachern[25] reported a case of recurrent complete heart-block in an individual with general and coronary arteriosclerosis. They too regarded the sudden and frequent shifting from normal sinus rhythm to complete heart-block as being dependent upon vascular sclerosis with a deficient blood supply to the A-V node.

Levine's case (Case 14, Table I) was the only instance in which the left coronary artery alone was involved, or rather where the right coronary artery was not at all involved, and probably falls into the 8 per cent group in which the artery to the A-V node arises from the left coronary artery after crossing the "crux" of the heart.

CLINICAL SIGNIFICANCE

The clinical differentiation between right and left coronary artery occlusion has engaged the attention of many clinicians. The work of numerous investigators,[7, 8, 9, 16] shows that infarction of that portion of the myocardium usually supplied by the right coronary artery is associated with inversion of the T-waves in Leads II and III, whereas infarction of the myocardium supplied by the left coronary artery is associated with inversion of the T-waves in Leads I and II. The appearance of complete heart-block during an attack of acute coronary artery thrombosis points to involvement of the right coronary artery in about 93 per cent of the cases. If in addition to this we have other clinical signs such as rapid enlargement of the liver, as emphasized by Libman, the clinical diagnosis of right coronary artery occlusion can be made with greater certainty.

SUMMARY AND CONCLUSIONS

A case of transient complete heart-block occurring during an attack of acute coronary artery thrombosis is described in detail. Changes in the ventricular portion of serial electrocardiograms conform to type T_3, indicating myocardial damage as the result of occlusion of the right coronary artery.

The transient nature of A-V dissociation during an attack of coronary artery thrombosis has been explained on the basis of the peculiar anat-

omy of the blood supply to the A-V node. Permanent heart-block without any demonstrable lesions of the node or main stem may be explained on the same basis.

The observations on the case presented and a review of similar cases reported in the literature indicate that in patients with coronary artery occlusion and complete heart-block, the right coronary artery is involved in approximately 93 per cent of the cases and the left in 7 per cent. The presence of complete A-V dissociation is therefore believed to be a valuable diagnostic criterion in the clinical differentiation between right and left coronary artery thrombosis.

I am greatly indebted to Dr. Marcus A. Rothschild, Dr. Sidney P. Schwartz, and Dr. Ernst P. Boas for furnishing me with clinical data and electrocardiograms of cases which they observed but have not published.

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THE EFFECT OF TONSILLECTOMY ON THE OCCURRENCE AND COURSE OF ACUTE POLYARTHRITIS*†

An Analysis of 654 Consecutive Case Histories

Maxwell Finland, M.D., and William H. Robey, M.D.
Boston, Mass.
and
Harry Heimann, M.D.
Brooklyn, N. Y.

THE problem of focal infection and its relation to the etiology of rheumatic diseases and their recurrence has been much studied and discussed in recent years. Recent work upon the bacteriological and immunological aspects of rheumatic diseases has emphasized the importance of this concept, and most writers have stressed the rôle of the tonsils as an important focus. The object of this paper is to consider the present day beliefs concerning this possible source of systemic infection.

Tonsillitis, acute or chronic, is a medical disease and as such is usually entirely under the direction of the general practitioner. Even in the eventuality of tonsillectomy the patient is urged or dissuaded according to the beliefs or doubts of his medical adviser.

The virulence of a given attack of tonsillitis is difficult to estimate. A seemingly mild tonsillitis may have dire effects upon other structures, while a much more violent local reaction may pass, leaving little but weakness and prostration, and be followed by apparently complete recovery. The physician has little difficulty in recognizing an attack of acute tonsillitis. The diagnosis of the chronic form may be more difficult. Slight degrees of sore throat may make but little impression on the patient's mind, and he may fail to mention them in giving his medical history, or they may not have recurred for so many years that they are entirely forgotten. In attempting to explain undefined ill health, the physician should take into consideration a history of previous sore throats, for the tonsils once infected, even though quiescent for years, have proved in numerous cases still to harbor infection.

It has been shown[1] that the tonsils may be enucleated with safety during the acute stage of rheumatic fever. The present study was made to determine, if possible, whether or not the enucleation of the tonsils at any time has any effect upon the recurrence of rheumatic fever. Since our material is based entirely upon the examination of case histories, no

*From the Thorndike Memorial Laboratory, Second and Fourth Medical Services (Harvard), Boston City Hospital and the Department of Medicine, Harvard Medical School, Boston.
†Read before the American Climatological and Clinical Association at Absecon, New Jersey, on May 6, 1932.

great emphasis can be laid upon the accuracy of details. The results, however, have brought out interesting comparisons and observations.

For the purposes of this study consecutive cases were taken from the four medical services of the Boston City Hospital during a five-year period between January 1, 1924, and December 31, 1928. Such a period was chosen to avoid, if possible, annual fluctuations in the occurrence of rheumatic diseases and in the type of manifestations. In order to limit the size of the study and to secure an easily segregated and clean-cut group of cases, only those admitted for acute migratory polyarthritis were selected. Any who were suspected of having specific etiology or who later developed permanent changes in the joints were excluded. Of a total of 654 cases thus obtained, 114 had been operated upon for tonsillectomy prior to admission. Our attention was directed chiefly to tonsillectomy and its results, since the medical treatment was essentially the same in all. The latter consisted primarily of large doses of salicylates or their substitutes when the former were not well tolerated. In addition to determining the efficacy of tonsillectomy in the various aspects of the disease, other interesting observations were thought worthy of recording as they have brought out points not commonly appreciated.

ANALYSIS OF CASE HISTORIES

Age and Sex Distribution.—The distribution of the cases according to decades and between the sexes is shown in Table I, and the percentage incidence of cases in the various decades, when allowance is made for the fact that no patients are admitted to the regular medical wards before the age of twelve years, shows a progressive decline with increasing age. There is also a predominance of males, approximately in the proportion of three to two. The predominance of males may be in part accounted for by the character of the hospital population. This, however, was not analyzed in detail. It is interesting to observe the large number of persons in the older age groups, a fact not commonly appreciated. The figures in some of the later tables are also arranged according to decades

TABLE I

AGE AND SEX INCIDENCE

AGE (YEARS)	MALES	FEMALES	MALES AND FEMALES	PERCENTAGE OF TOTAL
12-19	90	65	155	23.7
20-29	97	90	187	28.6
30-39	87	54	141	21.5
40-49	61	43	104	15.9
50 and over	44	23	67	10.2
	379	275	654	100.

in order to emphasize the similarity of the various details of the disease in the later as well as in the earlier decades.

Incidence of Recurrences.—In the group of 654 cases studied, 335 were admitted for an initial attack, and the remaining 319 cases, or 49 per cent, were admitted for recurrences. The percentage of cases in each age group with previous attacks of polyarthritis is strikingly uniform (Table II).

TABLE II

FREQUENCY OF PREVIOUS ATTACKS OF ACUTE POLYARTHRITIS

AGE GROUP	CASES IN AGE GROUP	CASES WITH PREVIOUS POLYARTHRITIS	PERCENTAGE OF AGE GROUP
12-19	155	72	46.5
20-29	187	89	47.6
30-39	141	65	46.1
40-49	104	50	48.1
50 and over	67	43	64.2
All ages	654	319	48.8

Recurrences in Relation to Previous Tonsillectomies.—In Table III are shown the numbers and percentages of patients in each of the various decades who were admitted for initial or subsequent attacks of acute migratory polyarthritis, and who had been previously subjected to tonsillectomy. It is seen that 42, or 6.4 per cent, of the patients who were admitted for an initial attack had already had their tonsils removed. Seventy-two cases, or 11 per cent, were admitted for subsequent attacks after tonsillectomy, giving a total of 114 cases or 17.4 per cent of a total of 654 cases admitted for acute polyarthritis subsequent to tonsillectomy. In other words, of the 335 patients admitted for an initial attack 42, or 13 per cent, had previously had tonsillectomy, whereas 72, or 23 per cent,

TABLE III

FREQUENCY OF HISTORY OF RECURRENT ATTACKS OF POLYARTHRITIS IN CASES PREVIOUSLY SUBJECTED TO TONSILLECTOMY

AGE GROUP (YEARS)	CASES IN AGE GROUP	CASES WITH PREVIOUS TONSILLECTOMY					
		TOTAL CASES	PERCENTAGE OF AGE GROUP	ADMITTED FOR INITIAL ATTACK	PERCENTAGE OF AGE GROUP	ADMITTED FOR RECURRENCE	PERCENTAGE OF AGE GROUP
12-19	155	58	37.4	25	16.1	33	21.3
20-29	187	34	18.2	12	6.4	22	11.8
30-39	141	18	12.7	5	3.5	13	9.2
40-49	104	4	3.8	0	0	4	3.8
50 and over	67	0	0	0	0	0	0
All ages	654	114	17.4	42	6.4	72	11.0

of the 139 patients admitted for recurrences previously had had tonsillectomy. Thus twice the percentage of cases previously subjected to operation were admitted for a recurrence as were admitted for an initial attack. The proportion is quite similar in each of the age groups.

Frequency of Sore Throat in Relation to Tonsillectomy.—In this category are included all cases who had had sore throats, diagnosed "septic throat," "acute tonsillitis," "acute pharyngitis" or similar diagnoses, in which the throat symptoms began either with the onset of the joint symptoms or preceding them by a period not exceeding fourteen days. There were in all 281 cases, or 43 per cent, having sore throats with or before the attack. Of the 114 cases who had previously had a tonsillectomy 50, or 44 per cent, began with sore throats, whereas 231, or 43 per cent, of the 540 cases not previously subjected to the operation had had an antecedent sore throat. It would appear that the attack of acute polyarthritis was just as frequently preceded by throat symptoms in the group subjected to tonsillectomy sometime previous to admission as in those who had never been operated upon. In this same connection, it is interesting to note that 50, or 44 per cent, of the 114 cases who had had their tonsils removed before entry, were found to have tonsillar tissue on simple inspection of the throat during the admission physical examination.

Frequency of Rheumatic Heart Disease.—The frequency with which a diagnosis of rheumatic heart disease was made or suspected at the time of entry in the present group of cases is shown in Table IV. It is seen that 67, or 59 per cent, of the 114 cases previously operated upon had, or were suspected of having, heart involvement at the time of entry. Among the cases who had no previous operation, 202, or 37 per cent, had, or were suspected of having, rheumatic heart disease on admission to the hospital. This makes a total of 269, or 41 per cent, of all of the cases with heart lesions diagnosed or suspected at entry. Among these cases

TABLE IV

FREQUENCY WITH WHICH THE DIAGNOSIS OF "RHEUMATIC HEART DISEASE" WAS MADE OR SUSPECTED AT THE TIME OF ADMISSION

	CASES WITHOUT PREVIOUS TONSILLECTOMY			CASES WITH PREVIOUS TONSILLECTOMY			ALL CASES		
AGE (YEARS)	CASES IN AGE GROUP	R. H. D. DIAGNOSED	R. H. D. SUSPECTED	CASES IN AGE GROUP	R. H. D. DIAGNOSED	R. H. D. SUSPECTED	CASES IN AGE GROUP	R. H. D. DIAGNOSED AND SUSPECTED	PERCENTAGE OF AGE GROUP
12-19	97	28	26	58	25	11	155	90	58.1
20-29	153	32	25	34	15	7	187	79	42.2
30-39	123	15	16	18	4	4	141	39	27.7
40-49	100	21	10	4	1	0	104	32	30.8
50 and over	67	15	14	0	0	0	67	29	43.3
All ages	540	111	91	114	45	22	654	269	41.1

heart lesions were therefore about one and one-half times as frequent in those whose tonsils had been removed as they were in those not subjected to the operation.

When analyzed according to whether the patients were admitted for the first or for a subsequent attack, it was seen that 92, or 29 per cent, of the 319 cases admitted for the first attack had had, or were suspected of having, heart involvement at the time of entry, as compared to 175, or 53 per cent, of the 335 patients admitted for a recurrent attack who were similarly affected. In other words, rheumatic heart disease was about twice as frequent in the group of cases admitted for recurrent attacks as among those admitted for an initial attack. Considering both of these findings it may be said that previous tonsillectomy had no striking effect in reducing the incidence of cardiac lesions at the time of admission to the hospital in this series of cases.

EFFECT OF TONSILLECTOMY ON THE ATTACK

For the purpose of comparing the cases which had never been subjected to tonsillectomy with those admitted subsequent to the operation and also with those subjected to tonsillectomy during their stay in the hospital, it was necessary to choose certain criteria which were both simple and easy to determine from the case records. Three such facts were selected:

1. The duration of joint symptoms.
2. The duration of fever.
3. The duration of hospitalization.

Fever was considered present when the temperature rose to or above 99.4° F. In order to ascertain whether or not the cases were comparable at the time of admission to the hospital, the only criterion that could be used was the first, namely, the duration of joint symptoms at the time of admission, this being the most reliable symptom obtainable from the patient.

Duration of Joint Symptoms at Entry.—In Table V is shown the duration at the time of entry of the joint symptoms in the cases studied. These were subdivided into groups according to the duration of symptoms and the patients divided further into those previously operated upon, those operated upon in the hospital, and those having no operation. The percentage incidence in each of the latter groups is indicated in the table and is shown graphically in Fig. 1. From this illustration it may be seen that the groups were quite comparable with regard to the duration of joint symptoms at the time of entry, the curves for each of these groups running closely together and crossing frequently.

Total Duration of Joint Symptoms.—The cases were analyzed in a similar manner with regard to the total duration of symptoms from the time of onset to the time when the joint symptoms were last noted, and the results are shown in Table VI and represented graphically in Fig. 2.

TABLE V

DURATION OF JOINT SYMPTOMS AT ENTRY*

DURATION AT ENTRY (DAYS)	OPERATION BEFORE ADMISSION		OPERATION DURING HOSPITALIZATION		NO OPERATION	
	NUMBER OF CASES	PERCENTAGE DISTRIBUTION	NUMBER OF CASES	PERCENTAGE DISTRIBUTION	NUMBER OF CASES	PERCENTAGE DISTRIBUTION
0-7	51	44.7	52	34.2	151	38.4
8-15	20	17.5	30	19.7	94	23.9
16-31	27	23.8	42	27.6	99	25.2
32-63	10	8.8	20	13.2	40	10.2
64+	6	5.3	8	5.3	9	2.3
All cases	114	100.0	152	100.0	393	100.0

*Including cases reoperated during hospitalization.
Cases where data were not given are excluded in this and the following tables.

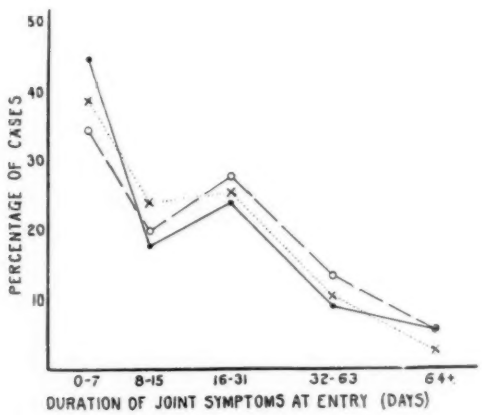

Fig. 1.—In this and the following illustrations:
.————————. Cases with tonsillectomy before admission.
o- - - - - - -o Cases having tonsillectomy in hospital.
x. . . . . .x Cases without tonsillectomy.

From a study of the latter figure, it appears that the cases previously subjected to tonsillectomy, as indicated by the solid line connecting the dots, and the cases having no operation, as represented by the dotted line connecting the crosses, were quite comparable with respect to the total duration of the joint symptoms, inasmuch as these curves are not widely divergent and cross early and again later. On the other hand, the cases that were operated upon in the hospital, indicated by the interrupted line connecting the circles, have a lower incidence among the groups having a short duration and a slightly higher incidence among those having a longer duration of joint symptoms. This does not appear very strikingly but is definitely suggestive. It is, however, quite comprehensible if we consider that a number of patients who were operated upon during a pe-

TABLE VI

TOTAL DURATION OF JOINT SYMPTOMS

DURATION (DAYS)	OPERATION BEFORE ADMISSION		OPERATION DURING HOSPITALIZATION		NO OPERATION	
	NUMBER OF CASES	PERCENTAGE DISTRIBUTION	NUMBER OF CASES	PERCENTAGE DISTRIBUTION	NUMBER OF CASES	PERCENTAGE DISTRIBUTION
15 or less	33	29.2	26	17.0	95	25.3
16-30	29	25.7	45	29.4	122	32.5
31-60	33	29.2	52	34.0	122	32.5
61-90	8	7.1	19	12.4	25	6.7
91 or more	10	8.9	11	7.2	11	2.9
	113	100.0	153	100.0	375	100.0

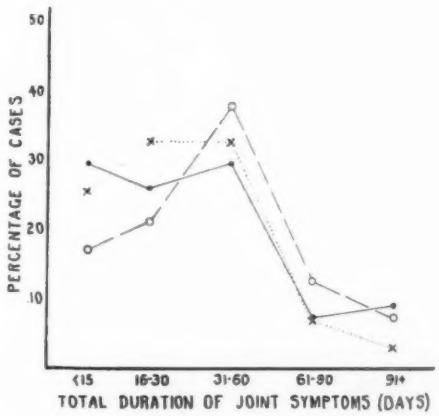

Fig. 2.

riod when they were not having joint symptoms had a recrudescence of symptoms subsequent to the operation.

Duration of Fever in the Hospital.—The cases were studied with respect to the total number of days of elevated temperature above 99.4° F., and the results tabulated in a manner similar to that in which the joint symptoms were studied. The results are shown in Table VII and represented graphically in Fig. 3. The three curves in this figure are of the same form and run very close together, showing that with respect to the duration of fever in the hospital there was very little difference between those patients having had no tonsillectomy at all, those subjected to this operation before entry, and those operated upon in the hospital.

Duration of Hospitalization.—A similar study was made of the duration of hospitalization in these cases, and the results are shown in Table VIII and in Fig. 4. Here we see a progressive change in the shape of the curves, the curve representing the cases which had had no tonsil-

TABLE VII

DURATION OF FEVER IN THE HOSPITAL

DURATION (DAYS)	OPERATION BEFORE ADMISSION		OPERATION DURING HOSPITALIZATION		NO OPERATION	
	NUMBER OF CASES	PERCENTAGE DISTRIBUTION	NUMBER OF CASES	PERCENTAGE DISTRIBUTION	NUMBER OF CASES	PERCENTAGE DISTRIBUTION
0-7	80	70.1	107	68.1	289	72.8
8-15	15	13.2	30	19.1	54	13.6
16-30	13	11.4	14	8.9	40	10.1
31+	6	5.3	6	3.8	14	3.5
	114	100.0	157	100.0	397	100.0

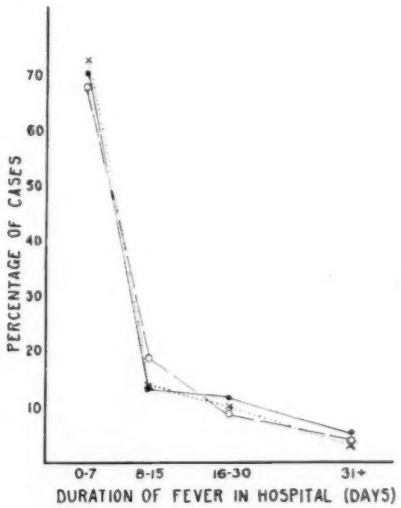

Fig. 3.

lectomy at all having the smallest percentage of cases in the shorter periods, and the greater percentage of cases in the longer periods. The cases subjected to tonsillectomy during the stay in the hospital have the lowest percentage in the shorter periods of hospitalization and the highest in the longer periods. The patients subjected to tonsillectomy before entry to the hospital, occupy an intermediate position. In other words, the patients who had no tonsillectomy at all had on the whole the shortest stay in the hospital, and those subject to tonsillectomy before entry had a somewhat longer period but were not in the hospital as long as those patients who were operated upon during their stay. The difference between those operated on before entry and those not operated on at all is only slight, but those operated on in the hospital show a fairly wide divergence.

TABLE VIII

DURATION OF HOSPITALIZATION

DURATION (DAYS)	OPERATION BEFORE ADMISSION		OPERATION DURING HOSPITALIZATION		NO OPERATION	
	NUMBER OF CASES	PERCENTAGE DISTRIBUTION	NUMBER OF CASES	PERCENTAGE DISTRIBUTION	NUMBER OF CASES	PERCENTAGE DISTRIBUTION
15 or less	31	27.2	19	12.1	139	35.0
16-30	34	29.8	51	32.5	124	31.1
31-60	36	31.6	67	42.7	103	26.2
61+	13	11.4	20	12.7	31	7.8
	114	100.0	157	100.0	397	100.0

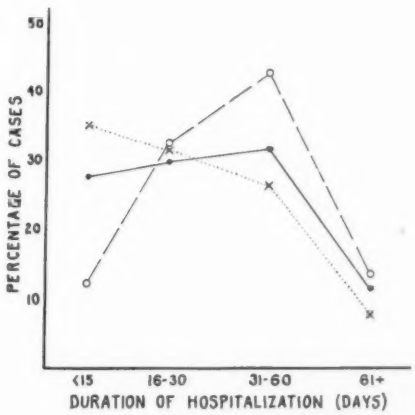

Fig. 4.

Evidence of Active Rheumatic Heart Disease During Observation.—Patients were considered to have active rheumatic heart disease when one of the following was present: changing endocardial murmurs, pericarditis, pancarditis, arrhythmias, disturbances of conduction, easily accelerated pulse rate, or decompensation.

Among the 114 patients who had had a tonsillectomy before entry, 33, or 29 per cent, had active rheumatic heart disease while under observation, as compared to 104, or 19 per cent, of those patients who had had no tonsillectomy before entry. When the latter cases are subdivided into those operated upon in the hospital and those having no operation at all, we find that 21, or 15 per cent, of the 143 patients operated upon in the hospital who were not previously subjected to tonsillectomy, were observed to have active rheumatic cardiac lesions, whereas 83, or 21 per cent, of the 397 cases who were at no time subjected to tonsillectomy had similar lesions. It is only fair to assume that the lowest figure of 15 per cent among those patients operated upon in the hospital depends largely

upon the choice of cases for operation, inasmuch as most of the physicians in the hospital have advised against operating upon patients in whom active lesions were observed. However, the high incidence of active rheumatic heart lesions in the group admitted to the hospital subsequent to tonsillectomy is striking. It must, of course, be considered that these cases may represent the poorer risks, inasmuch as patients having frequent attacks as shown above are more subject to rheumatic heart disease, and they are the ones usually recommended by physicians for tonsillectomy. When analyzed on the basis of the diagnosis of rheumatic

TABLE IX

POSTOPERATIVE COMPLICATIONS (CASES OPERATED ON WHILE SYMPTOMS OF THE ACUTE DISEASE WERE STILL PRESENT ARE EXCLUDED)

MANIFESTATIONS	NUMBER OF CASES
Leucocytosis, with or without fever	18
Fever, leucocytosis and active cardiac lesion	6
Fever and arthritis	21
Arthritis or nodules or both	4
Severe sore throat with fever	2
Peritonsillar abscess	1
Postoperative hemorrhage	3

heart disease at entry, it was seen that 93, or 34 per cent, of 269 patients having rheumatic heart disease at the time of entry showed active cardiac lesions during their stay, whereas 44, or 11 per cent, of those patients not diagnosed or suspected of having rheumatic heart disease at entry had active rheumatic cardiac lesions during their stay in the hospital. That is to say, according to the criterion mentioned, about one-third of the patients who were admitted with some rheumatic cardiac lesion were active during the attack for which they were admitted, whereas 11 per cent of those not suspected of having any cardiac lesion at the time of entry developed evidence of lesions. Minor differences were observed between those patients operated on before entry and those not operated on.

Postoperative Complications.—In Table IX are listed the number of cases in which various complications occurred among those operated upon in the hospital, excluding the patients whose operation was performed during the acute stage of the disease. Approximately one-half of the patients who were operated upon while apparently quiescent showed evidence of activity following the operation, but in only six were there serious complications, as evidenced by the presence of active heart lesions following operation.

INCIDENCE OF INITIAL ATTACKS AND RECURRENCES IN RELATION TO TONSILLECTOMY

Age at First Attack.—In Table X the cases are grouped according to the decade at which the first attack occurred. It is, of course, seen that except for the earliest age group, the incidence of initial attacks declines progressively with each decade. The 41 patients admitted for a first attack subsequent to the removal of their tonsils are also grouped by decades. The absence of patients beyond the age of forty years possibly depends upon the rarity with which older individuals are recommended

TABLE X

AGE AT TIME OF FIRST ATTACK OF POLYARTHRITIS*

AGE AT TIME OF FIRST ATTACK	ALL CASES*	CASES NOW ADMITTED FOR FIRST ATTACK	
		WITH PREVIOUS TONSILLECTOMY	WITHOUT PREVIOUS TONSILLECTOMY
0-9	40		
10-19	210	25	56
20-29	164	12	82
30-39	117	4	67
40-49	72	0	53
50 and over	33	0	21
Total	636	41	279

*Excluding 18 cases with incomplete data. In the subsequent tables the cases with insufficient data are excluded.

for this operation rather than upon the frequency with which attacks tend to recur. The last column, indicating the patients who were admitted for an initial attack, again emphasizes the fact that although there is a progressive decline in incidence with each advancing decade, there is still a large number whose first observed attack occurs after the fourth decade.

Frequency of Attacks.—An attempt was made on the basis of the data obtained from the records to determine the frequency with which attacks occur according to the age at the onset of the disease, and also to determine the number of attacks in each of these age groups. The data for the cases not previously subjected to tonsillectomy are shown in Table XI. In general no marked differences are observed in the frequency with which attacks recur in the various age groups, although there appears to be some tendency for attacks to be farther apart through the fourth decade, and then to be more frequent again in the later decades. The average number of recurrences is only very slightly lower in those having their initial attack in the later decades. In Table XII the results of a similar study in those cases previously subjected to tonsillectomy are given. Here it will be seen that the average number of recurrences in

those cases admitted following tonsillectomy is about the same as those not previously operated upon. The attacks, however, are much closer together in the cases previously tonsillectomized. The attacks occurred on an average at the rate of one recurrence every 3.2 years in this group as compared to one every 5.4 years in those not previously operated upon. It is interesting to observe that in the patients previously operated upon the average lapse from the time of tonsillectomy to the time of entry was

TABLE XI

FREQUENCY OF ATTACKS IN CASES NOT PREVIOUSLY SUBJECTED TO TONSILLECTOMY

AGE AT INITIAL ATTACK	CASES ADMITTED FOR RECURRENCE	FREQUENCY OF RECURRENCE*	AVERAGE NUMBER OF ATTACKS
0-9	23	4.7	4.0
10-19	90	5.6	3.1
20-29	58	5.7	2.8
30-39	41	6.8	2.5
40-49	18	4.5	2.9
50 and over	12	3.1	3.3
All cases	242	5.4	3.0

*Average lapse, in years, between attacks.

TABLE XII

FREQUENCY OF ATTACKS IN CASES PREVIOUSLY SUBJECTED TO TONSILLECTOMY

AGE AT INITIAL ATTACK	CASES ADMITTED FOR RECURRENCE	FREQUENCY OF RECURRENCE	AVERAGE NUMBER OF ATTACKS	FREQUENCY OF RECURRENCE AFTER TONSILLECTOMY	AVERAGE NUMBER OF ATTACKS AFTER TONSILLECTOMY
0-9	16	4.2	3.4	3.8	2.1
10-19	37	2.9	3.1	2.9	2.1
20-29	11	4.7	2.5	3.9	1.8
30-39	5	2.1	2.4	2.4	1.2
40-49	1	0.7	4.0	0.5	4.0
50 and over	0	0.	0.	0.	0.
All cases	70	3.2	3.1	3.2	2.0

6.5 years and during this period there occurred an average of 2.0 attacks per patient. The frequency of attacks following tonsillectomy is strikingly similar in these cases to the frequency of recurrences following the initial attack. Sixty-five of the patients who were subjected to tonsillectomy before admission to the hospital were this time admitted for the first attack after their operation. Forty of these patients had had no attacks previously and twenty-five had attacks before their operation. The average lapse of time from the operation to the time of entry in those who had never had previous attacks was 6.4 years, and in the twenty-five patients now admitted for a recurrence—this being the first attack after

the operation—the lapse from the time of tonsillectomy averaged 6.0 years. The figures are strikingly similar.

COMMENT

The cases included in the analysis here presented were very carefully chosen in such a manner that no doubt can exist as to the type of cases admitted. No claim is made that all of these cases represent cases of rheumatic fever, and no attempt is made into the controversy as to the differentiation of those cases of acute polyarthritis which may be included under the term rheumatic fever and those which should be designated acute infectious arthritis. Whether or not these cases should be so differentiated is of no great significance from the point of view of the material at hand. In this present study, and from the material analyzed, such differentiation was well-nigh impossible.

The operation of tonsillectomy has been recommended and is being recommended for patients with rheumatic diseases by a large majority of physicians in face of a great amount of accumulated evidence tending to indicate that this operation has had very little or no demonstrable benefit upon the possibility of recurrences. The present data only confirm the previous work on this subject. It is further shown here that the individual attack is practically unaffected by the fact of previous removal of tonsils. The findings of more frequent attacks in patients previously subjected to tonsillectomy may, of course, have its basis in the fact that patients are recommended for tonsillectomy only when they are observed to have frequent attacks, and the longer duration of joint symptoms, as well as the long duration of hospitalization, as has already been inferred, is probably due to the number of patients having slight recurrences following the operation who are kept in the hospital a somewhat longer period in order to be observed following their operation.

On the basis of the frequent observation of sore throats preceding rheumatic manifestations, as intimated in the findings recorded, it would seem that removal of tonsils should eradicate an important focus of infection and thus decrease the possibilities of recurrences. In individual cases, apparently striking benefit is observed even when the tonsils are enucleated during the disease, but obviously this is not always the case. The explanation for the poor results following operation is not entirely clear. We have mentioned above that about one-half of the operated cases were recorded as having tonsillar tissue at the time of admission. It is possible that incomplete removal of tonsils may be harmful, as the infected focus may become buried in scar tissue following the operation. Other foci may be overlooked or inaccessible.

Finally, what deductions shall we make from this investigation? In a large series of cases such as have been reported here and in other studies it must be remembered that a great number of operators of varying degrees of experience is represented. It is a question whether such large

groups of cases gathered in this manner from the records of a large municipal hospital give a true estimate of tonsillectomy as a preventive of rheumatic fever. In private practice where the cases can be studied with great care and an operator of experience in this particular operation can be selected, the results are often far more satisfactory. One of us (W. H. R.) after years of private practice, feels that when this has been done, the procedure has often been highly justifiable and has fully accomplished its aim.

SUMMARY

The case records of 654 consecutive patients admitted to the Boston City Hospital for acute migratory polyarthritis were studied for the purpose of determining whether or not tonsillectomy has altered the course of the attack or has affected the frequency of recurrence.

Patients admitted to the hospital for acute polyarthritis who had been operated upon sometime previously had on the whole a very similar course in the hospital, as judged by the duration of joint symptoms, the duration of fever, and the duration of hospitalization, as those operated upon after admission to the hospital.

Patients subjected to tonsillectomy during their stay in the hospital for acute migratory polyarthritis had a slightly longer period of joint symptoms and of hospitalization than those not operated upon during their stay.

Tonsillectomy has had very little influence in these cases upon the frequency of recurrent attacks.

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ARRHYTHMIA OF THE HEART ASSOCIATED WITH CHEYNE-STOKES BREATHING*

Report of a Case Showing Auriculoventricular Block

J. Murray Steele, M.D., and Albert J. Anthony, M.D.
New York, N. Y.

THE number of reports that have been published of cases in which fundamental disturbances of the rhythm of the heart were found associated with Cheyne-Stokes respiration are few, although difference in cardiac rate between the apneic and respiratory phases has been common knowledge for many years. In the literature descriptions of only twelve cases of cardiac arrhythmia with extreme slowing of the rate during the respiratory phase other than simple changes of rate associated with the phases of Cheyne-Stokes respiration have been found, four of which have been studied by means of the electrocardiograph. The following case may, therefore, be not without interest.

M. S., Hospital No. 7507, a colored woman, fifty years of age, was admitted to hospital, September 24, 1930, complaining of shortness of breath and swelling of the legs. The past history was unimportant. No serious illnesses had been experienced before 1928, when slight rheumatic pains in both shoulders occurred, and the whole body, including the face and tongue, are said to have become swollen. At this time her blood pressure was found to be 200 mm. Hg systolic and continued at this level until two weeks before admission.

The onset of sudden attacks of intense dyspnea "like asthma" occurring almost every morning while walking to work culminated in a very severe attack with palpitation on July 4, 1929, relieved only by a hypodermic injection of unknown content. She stopped work, remaining at home until the second week of September, 1929, when the attacks of dyspnea disappeared but palpitation continued to recur on exertion. Work was now resumed for nine months during which she remained fairly well until edema of the ankles first appeared in July, 1930. Two days later, after climbing five flights of stairs, a severe attack of dyspnea occurred, the first one since September, 1929. From this time until admission her condition grew steadily worse; shortness of breath increased and edema extended from the legs to the thighs. By the end of August it involved the lower abdominal wall. Pain in the right upper quadrant of the abdomen appeared at this time and increased steadily in severity.

On admission, the patient was seen to be a moderately well developed and well nourished colored woman suffering from severe orthopnea and periodic dyspnea of Cheyne-Stokes type. There was frequent dry cough. No unusual conditions except those pertaining to cardiovascular disease were found during examination. The bases of the lungs on both sides were at the level of the tenth spinous process. The descent of the left lung on inspiration was less than that of the right. There were no areas of dullness. Many râles were present in the lower portions of both lungs.

The apical impulse of the heart was diffuse, but forceful. No thrills or shocks

*From the Hospital of the Rockefeller Institute for Medical Research, New York.

were felt. The maximal width of the area of relative cardiac dullness was in the fifth interspace, extending 14 cm. to the left of the midline, and 4.5 cm. to the right. A loud systolic murmur was present over the chest, front and back, louder on the left side. The second aortic sound was faint. An x-ray photograph taken on September 25 showed well marked enlargement of the heart to both the left and right sides, and dilatation of the aortic arch. The lung fields were hazy and the shadows at the hila were consistent with chronic passive congestion. The heart exhibited sinus rhythm with slowing of the rate during dyspnea. The systolic blood pressure measured 160, the diastolic 95 mm. of mercury. The pulse was of variable volume, becoming somewhat weaker and slower during the respiratory phases. The abdomen was protuberant and tympanitic. The liver was tender and extended 3 cm. below the costal margin. The spleen was not palpable. There was dullness in the lower part of the abdomen suggesting the presence of a small amount of fluid. Anasarca of the lower part of the back and of the legs was present. Pitting on pressure was easily demonstrated.

The urine did not reduce Benedict's solution. Albumin was present in large amounts. There were many hyalin and granular casts, red blood cells, white blood cells and epithelial cells. The standard urea clearance test was 37 per cent of normal (September 29). On September 25, the count of the red blood cells was 4,500,000. Estimation of hemoglobin (Sahli) was 88 per cent. The total white blood cells numbered 13,000, of which polymorphonuclear leucocytes were 77 per cent, lymphocytes 18 per cent, and mononuclears 5 per cent. The Wassermann reaction of blood serum was negative (September 26).

During the first forty-eight hours in hospital, edema increased and the Cheyne-Stokes cycles became longer, so that digitalis (digitan, Merck) 1.0 gm. was given on September 26, without waiting for the usual period of observation to elapse. Only a slight increase in urinary output followed and gain in weight continued. The administration of theocalcin was also of no avail. On September 30, a change in cardiac mechanism was noted—the transition from a slow rate during the respiratory phase to a rapid one during the apneic, became abrupt; the rate during apnea reached 160 per minute. When, on October 9, extreme slowing appeared during dyspnea, there having been no sign of improvement, digitan, which had been administered at the rate of 0.1 gm. a day, was discontinued.

The general condition of the patient then grew progressively worse; unconsciousness supervened during apneic phases which had now increased to thirty-five seconds in length. In contrast to these unfavorable circumstances, the grave disturbances of cardiac rhythm which had been present were replaced by the gradual moderate slowing such as had been observed during the respiratory phase on admission. Steady accumulation of edema was retarded for a brief period by the administration of salyrgan on October 24 and 26. Subsequent exhibition of 1.8 gm. of digitan between November 10 and 15 failed to be of any benefit. Use of the drug was stopped on the latter date because of the development of periods of coupled rhythm which bore little relation to the rhythm of the Cheyne-Stokes cycles. The inhalation of increased concentrations of oxygen failed to stop the periodicity of respiration, but increased concentrations of carbon dioxide always succeeded in doing so. Neither gas had any consistent effect upon the cardiac rhythm. On November 19 the patient became deeply comatose, the breathing continuously dyspneic, and the rhythm of the heart regular, continuing so until death on November 20.

On postmortem examination* the body was seen to be that of a well developed and well nourished adult negress. Soft edema of the feet, ankles and legs was present. The surfaces of the pleurae were smooth and glistening, except for occasional fine fibrous adhesions, especially at the apices. About 100 c.c. of thin, straw-colored fluid

*We are indebted to Dr. C. P. Rhoads for the report of this examination.

was present in the left, and about 200 c.c. in the right thoracic cavity. The surfaces of the lungs were smooth except for a few adhesions and several rounded, slightly raised areas 2 to 3 mm. in diameter, firm in consistency, yellowish gray on section, surrounded by a firm, fibrous capsule. The surface of the lungs was purple and glistening, and distended alveoli were clearly visible. The cut surface and the bronchi exuded thin, blood-tinged fluid. The pulmonary artery showed a moderate degree of atheromatous change in the prepulmonary part.

The pericardial cavity contained about 60 c.c. of thin, yellow fluid. The surfaces were smooth and glistening. The heart weighed 640 grams. As viewed in situ before section of the great vessels, the greatest diameter was 18 cm. from the apex to the midportion of the right auricle. The superior inferior diameter of the right auricle was 10.5 cm. There was very marked increase in the size of the heart, particularly of the right side. The epicardium was smooth and glistening and revealed a patch of fibrosis, gray in color, on the anterior surface of the left ventricle which measured about 3 cm. in diameter. The myocardium was firm, dark purplish red in color, and presented no gross evidence of sclerosis. The endocardium and the valves were without change. The coronary arteries showed a moderate number of raised, irregular, atheromatous plaques. The tricuspid valve measured 12.5 cm. in circumference, the pulmonary valve 9.0 cm., the mitral valve 12.0 cm., the aortic valve 8.7 cm. The thickness of the wall of the left ventricle was 1.6 cm., and that of the right 0.4 to 0.6 cm.

The aorta displayed a number of raised, irregular, yellow to yellow-white plaques, particularly marked in the arch and descending aorta. Ulceration, though rare, was occasionally seen. Otherwise the vessels of the thoracic and abdominal cavities did not present abnormalities.

The spleen and liver were both moderately and symmetrically enlarged showing the usual changes attributed to chronic passive congestion. A well marked infiltration of fat was present in the liver.

The right kidney was normal in appearance. The left, however, was markedly atrophied, weighing only 44 grams. The surface was nodular and two small cysts containing a cloudy fluid were present. The cortex was extremely irregular in thickness and in structure. The glomeruli, however, could be easily seen.

The combined weight of the adrenal glands was 60 grams. They were normal in size, color, shape and consistency. The pancreas weighed 80 grams and was likewise normal. No other unusual findings were observed. Permission for the removal of the brain was not granted.

On microscopic examination the heart and the bundle of His were without abnormality. The aorta showed a moderate degree of intimal thickening of a type attributable to arteriosclerosis.

The pulmonary alveoli contained a large amount of precipitated albumin. The capillaries of the alveolar wall were enormously distended, and the walls themselves seemed much thicker than is common, apparently due to increase in cells of interstitial tissue, mononuclears or fibroblasts. Many heart failure cells were present.

The liver, kidneys and spleen all presented marked intimal thickening of the smaller vessels and extreme passive congestion. The strands of liver cells became more and more shrunken and vacuolated as the center of the lobule was approached, until they were entirely replaced by erythrocytes. In addition to the changes in the kidney already mentioned, many sclerosed and hyaline glomeruli, and many dilated and atrophied tubules were seen. The adrenal glands were normal.

The anatomical diagnosis was hypertrophy and dilatation of the heart; congestion of lungs, liver, spleen and kidneys; arteriosclerosis of aorta and coronary vessels; healed tuberculosis of lung and spleen; ascites and hydrothorax. The microscopical diagnosis was congestion of lung, spleen and liver; generalized arteriosclerosis.

ELECTROCARDIOGRAMS

A study of the first electrocardiogram which was obtained on September 25, shows slowing of the cardiac rate during the respiratory phase which was noted also on direct physical examination (Fig. 1). The average rate during the respiratory phase is 83, but it varies from 72 to 108 per minute. During the respiratory phase, P_1 changes in form, being frequently inverted. Since the variant P-waves occur when the interauricular intervals are longest, it seems probable that marked slowing of the normal pacemaker allows a lower portion of the auricle or a portion of the auriculoventricular system to take over this function. P_2 during an apneic phase becomes regular at a rate of 115 per minute and is constant in form with the exception of the last complex but one.

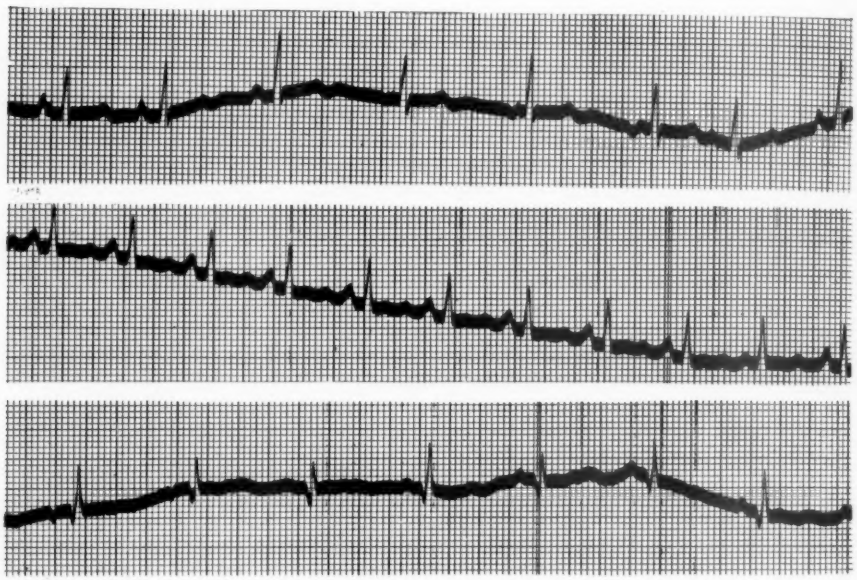

Fig. 1.—The three standard leads in order from above downward are shown of an electrocardiogram taken September 25, the day after admission. Leads I and III were taken during a respiratory (rate 82), Lead II during an apneic (rate 108) phase. The P-waves vary in form during dyspnea. In these, as well as in the other reproductions of electrocardiograms in this paper, divisions of the ordinates equal 10-4 volts; divisions of the abscissae equal 0.04 of a second. The original curves are sharply contrasted black and white; no half tones are lost by the method of reproduction. They are reduced to three-quarters of the original size.

On October 1, after the administration of 1.5 gm. of digitan in five days, the change from the slow rate during respiration to the rapid rate during apnea became abrupt instead of gradual. During apneic periods a series of ectopic ventricular beats occurs at a rate of 148 per minute (Fig. 2, Lead I) and during transition from apnea to dyspnea various forms of abnormal ventricular complexes (Fig. 2, Leads II and III). A similar phenomenon has been reported by Wassermann.[1] The auricular rhythm is irregular and blocked auricular impulses occur (one follows the fifth ventricular complex in Lead II, and another possible one after the eighth in Lead III). Such an occurrence has been described by Wilson and Robinson.[2] Three days later while digitan was still being given in daily doses of 0.2 gm. (Fig. 3, Lead III), a photograph of the end of a paroxysm of ventricular tachycardia was secured. The slow rhythm which follows is apparently associated with irregular auricular action

(coarse fibrillation). The amount of digitan was accordingly reduced to 0.1 gm. per diem.

Five days later, on October 10, an extremely slow rhythm during the respiratory phase made its appearance (Fig. 4, Lead II); digitan was discontinued altogether. With the first respiratory movement (Fig. 4, upper strip) the cardiac cycle begins to lengthen. Increase in the P-R intervals begins at the same time. At the peak of the

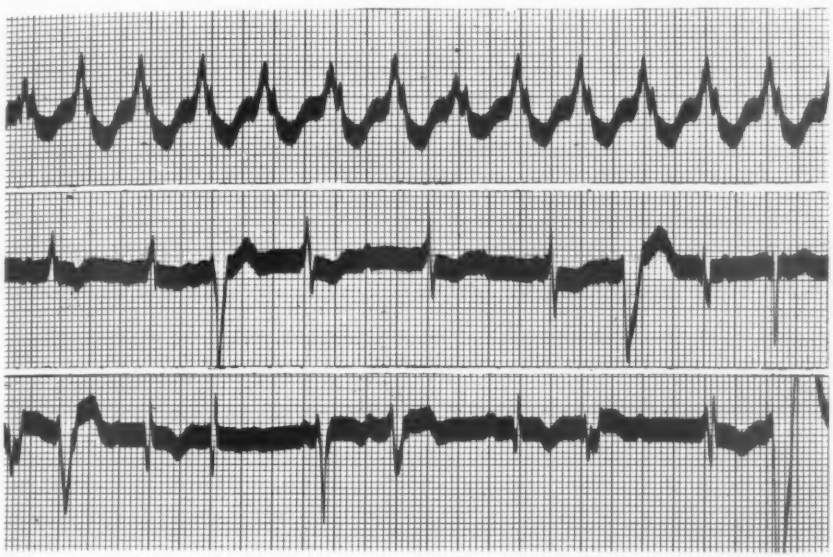

Fig. 2.—The three standard leads in order from above downward are shown of an electrocardiogram taken October 1. Lead I, taken during apnea, shows a series of ectopic ventricular beats (rate 148); Leads II and III, taken during dyspnea, display many different forms of ventricular beats. In Lead II the first and second, in Lead III the seventh ventricular complexes are the only normal ones. These records as well as those in Figs. 3, 4, and 5 were obtained after the administration of digitalis.

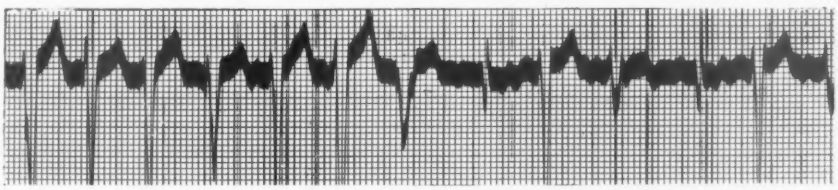

Fig. 3.—Lead III of an electrocardiogram taken October 4 is shown, in which a paroxysm of ventricular tachycardia terminates in a slow ventricular rhythm with auricular fibrillation. This is the only occasion on which auricular fibrillation was observed in this patient.

second inspiration the P-R interval has increased to 0.40 second; in the next cycle auriculoventricular block (2 to 1) is established and continues until the fourth respiration from the last. When the 1 to 1 sequence reappears, the P-R interval (Fig. 4, lower strip) is prolonged (0.25 second) in the first cycle only. The succeeding complexes are evenly spaced; their rate is 115 per minute. P_1 which is usually upright in this patient is inverted except in four instances. Two of them occur during periods of 1 to 1 rhythm, the first of these appearing at the moment of the first respiratory movement; the third introduces normal sequence following a period of incomplete block, the fourth occurs after a premature ventricular beat.

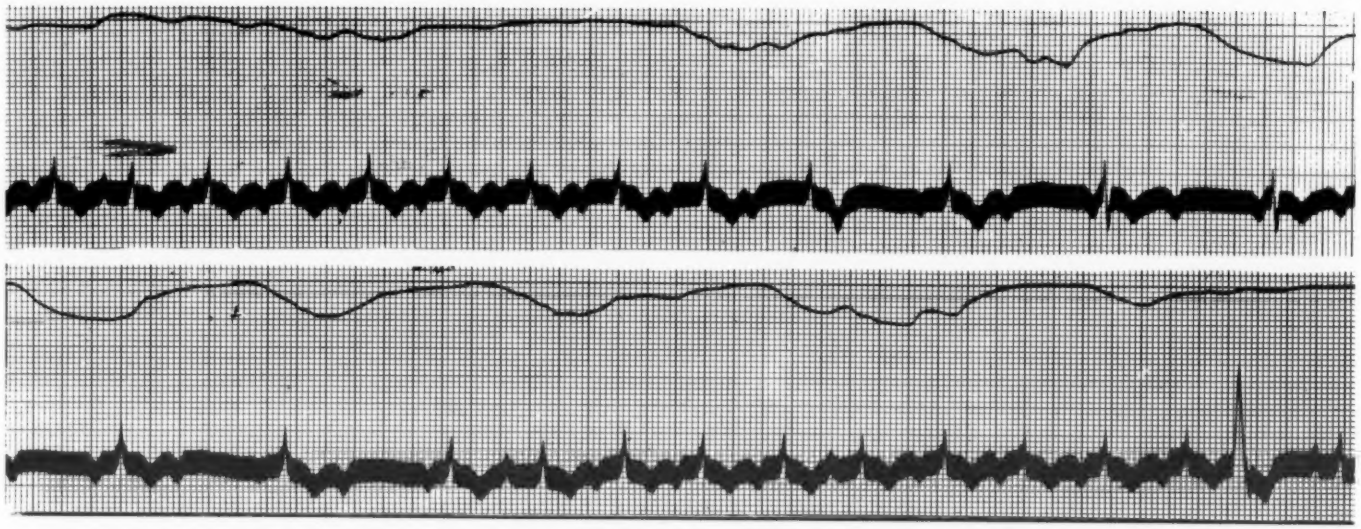

Fig. 4.—Two strips from a continuous record of Lead II during a cycle of Cheyne-Stokes respiration are shown in which the respiratory movements are recorded (inspiration down—expiration up) above the electrocardiogram. The upper strip is taken at the beginning of the respiratory phase, and the first movement appears to be expiratory (the upward movement between the first and second ventricular complexes). An upright P-wave occurs at about this moment. Incomplete block (2 to 1) appears after the second inspiratory movement and persists throughout the respiratory phase, the terminal portion of which is shown in the lower strip. The first P-wave of normal sequence, and one which follows a premature ventricular contraction are upright.

The events which occurred during the period when these electrocardiograms were made have been analyzed (Fig. 6). The curves display the relation of the disturbances of rhythm to the phases of the Cheyne-Stokes cycle. The beginning and the end of each respiration are exactly charted as to time. The height is proportional to the recorded amplitude. It is plain that sinus slowing and respiration begin at the same time. The

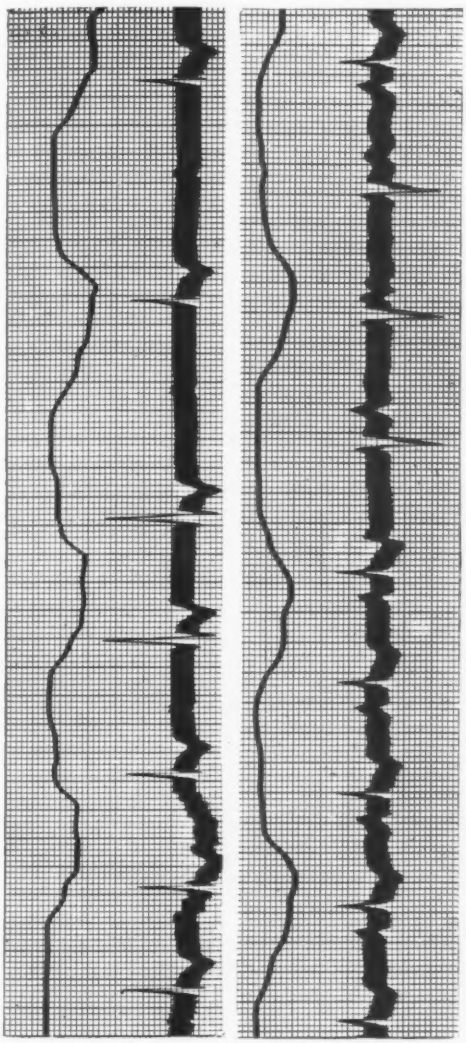

Fig. 5.—Two strips from an electrocardiogram taken October 11 are shown. The upper strip (Lead I) is from a portion of the record just after the beginning of the respiratory phase and shows two independent ventricular contractions (fourth and fifth), the first of which follows a P-wave after an interval of 0.44 second. The two succeeding normal ventricular complexes follow P-waves at intervals of 0.62 and 0.64 second respectively. In the lower strip (Lead II) the sixth, seventh, and eighth ventricular complexes are abnormal. The T-waves following these vary in form.

auricular rate is reduced from 115 to 104 beats per minute, while the ventricular beats are reduced to one-half the latter figure.

The next day, October 11, the mechanism of the slow rhythm during the respiratory phase was different (Fig. 5). The sinus node usually maintained its function as pacemaker, and the auricular rate was markedly slowed, but at times the ventricles initiated independent contractions (Fig. 5, the fourth and fifth complexes, upper strip). The fifth complex followed the auricular impulse at 0.44 second. The sixth and seventh ventricular complexes which are, however, similar to the usual ones, follow P-waves

after intervals of 0.64 second. As pointed out by Resnik and Lathrop[3] all these variations may be explained by the occurrences of impulses originating at different levels in the bundle of His. The appearance of incomplete block was observed only once on this day. Later during the next succeeding respiratory phase three more idioventricular contractions occurred (Fig. 5, lower strip). They are followed by T-waves of such diverse appearances as to suggest the presence of P-waves stimulated by ventricular contractions arriving at the auricles after varying intervals. When these two apparently dissimilar slow rhythms are compared, it appears that in the former (Fig. 4) conduction of impulses from auricles to ventricles is at fault without important change in the rate of impulse formation, while in the latter (Fig. 5), in which marked slowing of the pacemaker appears, various lower portions of the conduction system seem to have taken over the function of originating impulses. Disturbance of conduction is a minor factor but

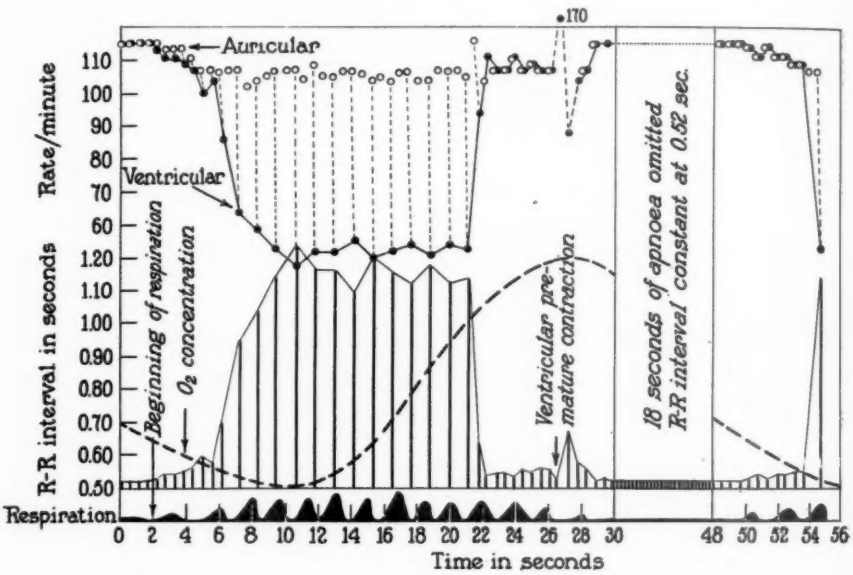

Fig. 6.—This chart shows the relations existing between the electrocardiographic phenomena and the phases of respiration during a little more than one cycle of Cheyne-Stokes breathing. The data were obtained from the continuous tracings of the electrocardiogram and respiratory movements simultaneously recorded on the same film; parts of this record are shown in Fig. 4. The auricular and ventricular rates are plotted in open and closed circles respectively, and those auricular contractions which are succeeded by ventricular beats are joined by broken lines to the ventricular beat which follows them. Ordinates represent time from the arbitrary zero when the chart begins; the particular ordinate upon which a ventricular beat is charted represents, therefore, the sum of all preceding R-R intervals. The curve of concentration of oxygen in the blood, being a curve made from data obtained in a study of other cases exhibiting Cheyne-Stokes respiration (Anthony, Cohn and Steele[6]), is drawn to show probable relations in respect to time only. Rise of the curve from the base line indicates increase in concentration.

contributes an influence on the form of the electrocardiogram. Both these rhythms resemble those which are known, however, to follow stimulation of the vagus nerves; the first exhibiting more especially the effect of stimulating the left, the second, the right vagus (Cohn[4]).

Six days after the administration of digitalis ceased (October 15) all disturbance of rhythm disappeared, leaving only during respiratory periods moderate sinus bradycardia and increase of the auriculoventricular interval from 0.16 to 0.18 second (Fig. 7). One month later, on November 14, after taking 1.6 gm. of digitan in four days, marked slowing of the rate during respiratory periods recurred (40 per minute, Fig. 8).

Again there was marked slowing of the pacemaker. But there may have been more than slowing of the rate of impulse formation, as may be inferred from the difficulty of finding evidence in the electrocardiogram of auricular activity after the third ventricular complex (Fig. 8, lower strip). The formation of impulses may indeed have been suppressed. The next few ventricular contractions would then be idiopathic in nature, but the form of the complex is so nearly identical that this cannot be definitely maintained. On November 15, after giving 0.2 gm. more of digitan, periods of coupled rhythm appeared, usually during apneic periods but without constant relation to the phases of respiration. Electrocardiograms were taken on November 16 during the exhibition of this rhythm. The inhalation of carbon dioxide exerted no consistent effects. Though cessation of periodic respiration took place, the coupled rhythm was once absent and

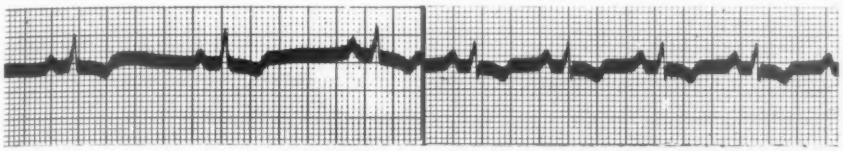

Fig. 7.—Two parts of an electrocardiogram (Lead II) are selected from a continuous record during a single cycle of Cheyne-Stokes respiration on October 15, six days after discontinuing the use of digitalis. The part on the left shows the slow rate during the respiratory phase; that on the right, the rapid rate during apnea.

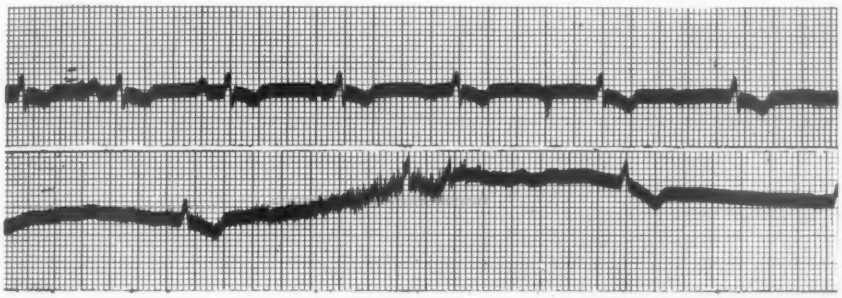

Fig. 8.—An electrocardiogram (Lead II), taken November 14 after the administration of digitalis, is shown. In the upper strip slowing of the rate, change in form of P-wave and increase of conduction time occur as the curve is read from left to right. The beginning of the respiratory phase is in the middle of the strip. The lower strip is continuous with the upper and exhibits extreme slowing of the auricular rate. The rapid oscillations about the fourth ventricular complex are artefacts.

once present. Oxygen administration failed to stop the periods of Cheyne-Stokes respiration, but coupled rhythm was again present at one time and absent at another. The only consistent difference concerned rate. During the administration of oxygen it was 80; during that of carbon dioxide, 100 per minute.

Twenty-four hours before death (November 19) the rhythm returned to normal sequence and constant rate with a somewhat prolonged auriculoventricular conduction time. Cheyne-Stokes respiration also disappeared. The administration of digitalis had been discontinued four days before.

DISCUSSION

This case is similar to that of Resnik and Lathrop in that it presents similar disturbances of cardiac rhythm. In order to analyze the relation of rhythmic and respiratory changes to changes in the composition of the

blood, samples of arterial blood were taken in a manner comparable with that employed by Resnik and Lathrop. The studies of Klein[5] and subsequent studies of our own[6] have shown that it is necessary, however, to take many samples in rapid succession during a respiratory cycle in order to secure evidence of the variations which take place in the content of gases. The samples taken in this case showed slight differences only in the concentrations of oxygen and carbon dioxide. An oxygen curve based on the variations found in other cases of Cheyne-Stokes respiration[6] has, however, been inserted in Fig. 6. This curve is not constructed on the basis of exact quantities, since these differ widely in different cases. The order of magnitude of change in oxygen concentration varied in our studies from 1 to 8 volumes per cent. The time relations between variations in the concentration of gases in the blood and phases of the respiratory cycle were, however, constant. It is with a view to emphasizing these relations that the curve is reproduced. The lowest concentrations of oxygen occur during the early portion of the respiratory phase, the highest during the end of the dyspneic or first part of the apneic phase. The changes in concentration of carbon dioxide occur in inverse relation.

Resnik and Lathrop suggested that periodic anoxemia, occasioned by periods of apnea superimposed upon anoxemia existing as a continuous state due to heart failure with edema, was sufficient to stimulate vagal activity (Greene and Gilbert[7]) and that it was this activity that was responsible for the disturbances of cardiac rhythm. The highest concentration of oxygen which they found occurred, however, during the period of greatest vagus stimulation. Very low concentrations of oxygen (7 or 8 per cent) must, furthermore, be reached before stimulation of the vagus takes place (Greene and Gilbert[8]). But attention must be called to the fact that the action of low tensions applies only to normal cardiac muscle. It is conceivable that diseased heart muscle, such as was present in the patient who forms the subject of the present study, may be more irritable, that is to say more sensitive, to vagal stimulation. Although the lowest concentration of oxygen occurred during the respiratory phase, so that a causal relation may be assumed to have brought on vagal stimulation, the concentrations usually attained do not seem low enough to be per se responsible for the result. The influence of other factors, change in hydrogen-ion content, periodic change in the irritability of the medullary centers or the presence of a drug capable of influencing the tone of the vagus nerves, must be taken into account. The last factor, digitalis, was present both in the case of Resnik and Lathrop and in our own. In our own, furthermore, extreme slowing, auriculoventricular block, appearance of idioventricular complexes, paroxysms of ventricular tachycardia and coupled rhythm were all present only while the patient was under the influence of the drug.

Many statements concerning the fact that change of rate and rhythm of the heart take place with the changing phases of Cheyne-Stokes respiration are to be found in the literature. Reports of illustrative cases, however,

are not numerous. The first two were reported by Gallavardin[9] in 1910 and 1911. He thought that the slow rhythm was due, in the first case, to incomplete auriculoventricular block (2 to 1), and in the second to coupled rhythm in which every second beat failed to cause pulsation at the wrist. He states that both of these rhythms occurred only while the patients were under the influence of digitalis.

Bäumler[10] in 1912 reported a case of heart failure in which Cheyne-Stokes respiration following a dose of morphia by less than twenty-four hours was observed fifteen days before death. During the height of the period of respiration on several occasions complete cessation of ventricular activity occurred, once for fifteen seconds: "Herzstillstand" was accompanied by a veritable Stokes-Adams syndrome. This patient, too, had received digitalis for a long period of time.

Roth[11] in 1916, included reports of several very interesting cases in a treatise on the effect of Cheyne-Stokes respiration on irregular action of the heart. In two cases of auricular fibrillation, marked slowing during the respiratory phase occurred. Atropin employed in one relieved slowing without affecting the periodicity of the breathing. Two cases with coupled rhythm exhibited marked slowing with dyspnea. One of these had been given digitalis; there is no mention of the use of the drug in the other case. The most interesting of all of his observations was that made after prolonged exhibition of digitalis in a patient with heart failure but without Cheyne-Stokes breathing. On walking about the room, dyspnea of sufficient degree occurred to bring on auriculoventricular block. Roth demonstrated this occurrence by means of simultaneous tracings of the jugular and apical pulses.

In 1925, Resnik and Lathrop's report appeared. Their patient too had received considerable digitalis. This was the first published electrocardiographic record of auriculoventricular block occurring during the respiratory phase of Cheyne-Stokes breathing. Fischer[12] in 1927, described a patient suffering from auricular flutter in whom during the period of apnea, flutter with or without incomplete heart block (2 to 1) was transformed into heart block, the ratio being 7 to 1 or even 8 to 1 during the respiratory phase after the administration of only 0.1 gm. of digitalis, an amount which seems too small to be of significance. Wenckebach[16] mentions a case of bigeminy, and Wassermann[1] two cases with ventricular tachycardia occurring during the period of apnea, in all three of which a great reduction in rate during the respiratory phase actually was apparent, but since they were used only as illustrative cases, no mention of therapy was made.

In thirteen cases in which great slowing in rate and disturbance of the basic cardiac rhythm took place during the dyspneic phase of Cheyne-Stokes respiration, nine had received considerable amounts of digitalis; in three, no mention of the use of the drug was made; in one, only 0.1 gm. of digitalis was given. In one case with heart failure, after prolonged use of

digitalis, a sudden attack of dyspnea induced a very slow rhythm. In view of the recognized effect of digitalis on the behavior of the vagus nerves, its presence in the organism must be considered as a potent influence in enhancing the strength of periodic vagal stimulation during Cheyne-Stokes respiration whether due to change in the center itself or to rhythmic deficit of oxygen.

SUMMARY

1. A case of heart failure is reported exhibiting Cheyne-Stokes respiration in which various types of cardiac arrhythmia were recurrently manifested during the dyspneic phases of the respiratory cycle.

2. Sinus slowing, prolongation of the P-R interval, partial and complete heart-block, and during suppression of the formation of sinus impulses, idiopathic ventricular rhythms were observed.

3. All of these changes in rhythm have previously been observed to follow various degrees of vagal stimulation.

4. With the exception of sinus slowing, all the phenomena occurred only after administration of digitalis in effective therapeutic doses.

5. Since digitalis has usually been administered in cases of Cheyne-Stokes breathing in which such disturbances of rhythm appeared during the dyspneic phase, it is suggested that the vagal effect of this drug is a powerful adjunct in their production.

Since this paper was prepared for publication, two articles dealing with reports of somewhat similar cases have come to our attention. Hamburger, W. W., Katz, L. N., and Rubinfield, S. H.: Am. Heart J. **7**: 498, 1932; and von Hoesslin, H.: Klin. Wchnschr. **11**: 971, 1932.

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THE ELECTROCARDIOGRAPHIC CHANGES FOLLOWING THE LIGATION OF THE SMALL BRANCHES OF THE CORONARY ARTERIES*

W. M. Fowler, M.D., H. W. Rathe, M.D., and Fred M. Smith, M.D.
Iowa City, Iowa

THE occurrence of a negative T-wave in the electrocardiogram following the experimental ligation of the coronary arteries in the dog was first observed by Kahn[1] in 1911. Smith[2] in 1918 described a series of successive changes in the electrocardiogram following the ligation of these vessels. In this investigation sixty-six dogs were used. The right coronary artery was ligated in eight, the anterior descending branch of the left coronary artery in eleven, the circumflex branch of the left coronary artery in fourteen and a combination of the various branches of the latter two vessels in thirty-three animals. Forty of these dogs survived the operation and were observed for periods ranging from two to ninety-one days. These observations were later checked in a series of twenty dogs in which various divisions of the anterior descending and circumflex branches of the left coronary artery were ligated.[3] Sixteen of this series recovered from the operation. Electrocardiograms were taken prior to the operation and in the vast majority at daily intervals during the first week to ten days of the postoperative course. After this period, records were obtained at one- to two-week intervals until the animal was sacrificed. The alterations in the electrocardiogram subsequent to the closure of the branches of the left coronary artery were successive and quite uniform in character. Soon after the ligation of either of the main branches of the left coronary artery the T-deflection became more prominent and in some instances approached, or even exceeded, the height of the R-deflection. Occasionally, the entire R-T segment was involved and arose from the descending limb of the R-wave well above the iso-electric line. The initial change in the electrocardiogram seemed to vary with the extent of the functional impairment of the myocardium. It was always greatest following the closure of either of the main branches of the left coronary artery, particularly the circumflex, and was most marked after a combined ligation of these vessels. This alteration might furthermore be magnified by increasing the work of the heart through the constriction of the aorta.

Within twenty-four hours the T-deflection became negative. The sharp character of the T-wave in the downward or even in the later upright position was a distinctive feature. The extent and duration of the

*From the Department of Internal Medicine, State University of Iowa, Iowa City, Iowa.

negative T-deflection in general varied with the size of the vessel ligated and possibly with the degree of the collateral circulation. In the animals in which the small branches were ligated the above alterations occurred in Lead I or in Leads I and II, whereas following the closure of either of the main branches of the left coronary artery it frequently appeared in all leads. The extent of the downward deflection gradually became less, and by the sixth to eighth day, or even in less time, changed to a positive phase in Lead III and later in Leads II and I. Occasionally the order was reversed in which the T-wave in Lead I became positive first, followed by a similar alteration in Leads II and III. These successive changes frequently continued until the T-wave was upright in all leads or at least in two derivations. This stage was usually observed in the second and fourth week and was often associated with a reduction in the amplitude of the R-deflection. Thereafter the rate of progression was much slower. In some the T-wave returned to the iso-electric line or even to a negative phase following which there was apparently no further alteration. Instances were recorded in which the T-wave was distinctly negative in all leads thirty-eight days after the ligation of the anterior descending branch of the left coronary artery. In other animals similar findings were observed in Leads II and III when sacrificed fifty to seventy days after the operation.

A reduction in the amplitude in the QRS group was observed by Smith, but not emphasized until a later report.[4] It was pointed out that this alteration followed a closure of the circumflex branch of the coronary artery in six (100 per cent), the anterior descending branch of the left coronary artery in two (20 per cent) and a combined ligation of the branches of these arteries in four (30 per cent). This change was observed as early as the second day. In some the amplitude returned to the original level, whereas in others it persisted until necropsy. The latter was noted particularly in the animals in which the circumflex branch was ligated. There was occasionally some slurring of the QRS group, but no distinctive increase in the duration of these complexes.

In the above investigation, premature contractions were often noted a few minutes following the ligation and were frequently present twenty-four to forty-eight hours after the operation. They occasionally occurred in runs and in some instances passed into a tachycardia which terminated in ventricular fibrillation and death. One animal with the circumflex branch of the left coronary artery ligated was cited which had many premature contractions throughout the postoperative period, and on two occasions was observed during paroxysmal tachycardia of ventricular origin. Lewis[5] previously had produced paroxysmal tachycardia by the ligation of the coronary arteries and this condition has since been encountered in man following coronary occlusion.

The experiments of Hamburger, Priest and Bettman[6] were similar in many respects to the investigations of Smith. These observers were

primarily interested in the occlusion of the smaller arteries and the production of a disseminated fibrosis of the myocardium in the dog through the introduction of a suspension of lycopodium spores into the coronary circulation. In some instances, however, the larger branches of the left coronary artery were completely filled, producing extensive areas of infarction comparable to that induced by the ligation of these vessels. Furthermore, the animals were studied electrocardiographically in much the same manner as in the ligation experiments. The electrocardiograms of the dogs that received overwhelming injections of the lycopodium suspension and died within a few minutes or during the first twenty-four hours showed conspicuous alterations in the T-deflection and in the R-T segment. In the animals which survived the injections for weeks or even months the successive changes in the T-wave were similar to those observed following the ligation of the coronary arteries. When the injection missed the lumen of the vessel "no permanent change in the electrocardiogram was found, although strange and curious findings were noted transitorily" which they attributed to trauma and hemorrhage produced by the manipulation.

Barnes and Mann[7] have more recently reported a series of experiments on twelve dogs in which the pericardium was opened in six, a posterior division of the circumflex branch of the left coronary ligated in three, and one or more branches of the right coronary artery ligated in three animals. They observed that the opening of the pericardium without further operative procedure produced successive changes in the T-wave and noted a significant deviation of the RS-T segment following the ligation of the branches of the right and left coronary arteries. The deviations in the RS-T segment, involving particularly Leads I and III, appeared immediately after the ligation and disappeared within twenty-four hours. Thereafter the alterations in the electrocardiogram concerned chiefly the T-deflection which passed through a series of changes similar to those previously described. While the RS-T segment deviations resulting respectively from the ligation of the branches of the right and left coronary arteries differed somewhat in their general character, the most important aspect concerned the direction assumed in Leads I and III. Following the ligation of the branches of the right coronary artery they were down in Lead I and upright in Lead III, whereas subsequent to the closure of a division of the left coronary artery, the reverse order prevailed. These investigators concluded that the RS-T segment deviations were distinctive for lesions of the right and left ventricle, but did not feel that the changes in the T-wave were necessarily indicative of a cardiac infarction, since this alteration was observed after the opening of the pericardium without the ligation of a vessel.

Otto,[8] Wood and Wolferth,[9] and Feil, Katz, Moore, and Scott[10] have

studied the early electrocardiographic changes following the closure of the coronary arteries in the dog. Otto observed a negative T-deflection with an ST fusion in Lead II immediately after the closure of the right coronary artery and an increase in the amplitude in the T-wave with a disappearance of the RT interval following ligation of the main division of the left coronary artery. Feil, Katz, Moore, and Scott ligated only the anterior descending branch of the left coronary artery. They concluded that the ligation of this vessel, in acute experiments, produced no characteristic RT deviation in the electrocardiogram, provided the cardiac mechanism remained normal. In further experiments, however, in which in addition to the closure of the above vessel the inferior vena cava was ligated for periods of five minutes, the typical alterations appeared. Wood and Wolferth, on the other hand, recorded definite alterations in the electrocardiogram following the temporary closure of various branches of the left coronary artery. In some instances an inverted T-deflection was the initial change, whereas in other experiments the opposite effect was produced; *viz.*, an elevation of the RT segment. These alterations disappeared soon after the clamp was removed from the vessel. The magnitude of the above changes seemed to depend on the vessel ligated, the extent of the infarction, and the duration of the occlusion. The ligation of the circumflex branch of the left coronary artery was more effective in producing the changes in the electrocardiogram. The most striking alterations, however, were observed following the combined ligation of the circumflex and the anterior descending branches of the left coronary artery. The size of the area of infarction and the extent of the functional impairment of the myocardium seemed to be the most important factors.

Clinical application of these experimental findings have been made by numerous observers and in those instances in which the initial electrocardiograms were taken soon after the cardiac accident and progress curves obtained at frequent intervals, the alterations agreed in every essential detail with those produced experimentally in the dog.[11, 12, 13, 14, 15, 16] The changes in the T-deflection duplicate those encountered in the experimental curves except for more rapid progression in the latter. The alterations pertaining to the reduction in the amplitude in the QRS group were likewise of the same general character. The greatest difference concerned the initial change in the electrocardiogram or the so-called R-T deviation. This feature was distinctly more prominent and lasting in the clinical electrocardiogram. This, however, is not unexpected in that the condition of the coronary arteries in the dog is not comparable to that ordinarily found with coronary occlusion. In the latter, because of the associated sclerosis of the coronary arteries the derangement of the myocardial function is likely to be more profound and the reparative process slower than that in the dog following

the closure of a corresponding vessel. There is, furthermore, a greater possibility of an extension of the myocardial damage, as indicated by Parkinson and Bedford[15] and as suggested by certain curves observed by the writers.

Alterations in the T-deflection have been produced experimentally by other means and have been observed clinically in conditions in which the coronary arteries were at least not primarily concerned. Eppinger and Rothberger,[17] in 1909, noted a negative T-wave following the injection of silver nitrate into the right basal portion of the heart, whereas an exaggerated deflection was obtained when the chemical was introduced into the left apical region. The opposite effect was induced by spraying the heart with ethyl chloride. Wilson and Herrmann[18] and Smith[3] also observed that localized temperature changes alone produced striking alterations in the T-deflection. Wilson and Finch[19] obtained similar results in man by having the subject drink ice water. Parade and Stepp[20] injected 40 per cent lipiodol solution into the myocardium through the intact chest wall and found that the T-wave became negative within twenty-four hours and in most instances subsequently returned to the original level. Porte and Pardee[21] observed three cases of rheumatic pericarditis with a negative T-wave in Leads I and II and at necropsy in one found an early fibrotic lesion with moderate cellular exudate beneath the epicardium. Similar electrocardiographic changes were noted by Scott, Feil, and Katz[22] in pericarditis with effusion. They also produced an alteration in the S-T segment and in some instances an inversion of the T-wave by the experimental introduction of fluid into the pericardial sac.[23] These results were attributed to the increased pressure on the heart and a consequent anoxemia. Cohn and Swift[24] recorded changes in the T-deflection during rheumatic fever which were regarded as being indicative of a myocardial involvement. These findings have since been confirmed by other observers. Suggestive alterations of the same general character have also been encountered during the course of pneumonia,[25] diphtheria, and scarlet fever.[26]

Recently Crawford, Roberts, Abramson, and Cardwell[27] have studied the effects of localized ventricular lesions on the electrocardiogram in the cat. These lesions were produced by electric cautery and were about ½ cm. in diameter and as deep as possible without penetrating the ventricular cavity. In order to facilitate the interpretation of their results, the ventricular wall was divided into eight regions, the left apex anterior, the left base anterior, the left apex posterior, the left base posterior, the right apex anterior, the right base anterior, the right apex posterior, and the right base posterior. These observers concluded that lesions in similar sites produced the same type of curve. Lesions on the anterior surface of the left ventricle gave a T_1 type of electrocardiogram, whereas those on the posterior surface of the left ventricle

including the apex produced the T_3 type. Cauterization of the right ventricle at the various sites indicated above, except possibly the anterior base, resulted in a curve of the T_3 type.

The ligation experiments so far recorded have been concerned for the most part with the larger branches of the coronary arteries. In the present investigation only the smaller surface branches were ligated in order to determine whether the closure of a vessel of this size would produce characteristic alteration in the electrocardiogram. The vessels selected on the left ventricle were usually the third or fourth subdivisions and a ligation was made a short distance proximal to their penetration of the myocardium. The influence of certain stages in the operative procedure on the electrocardiogram was also studied. It was hoped that these results might be helpful in the diagnosis of the occlusion of the smaller coronary arteries in man.

In this study, thirty-seven experiments were performed on twenty-four dogs. Five of these animals were subjected to two operations and four animals to three operations. The dogs were anesthetized with ether; a tracheal cannula was inserted and the anesthesia continued under positive pressure.

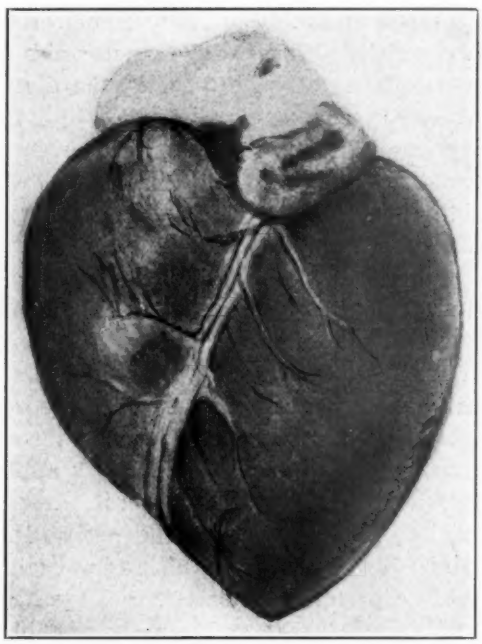
The chest wall was opened by an incision parallel to the sternum on either the right or left side, depending on which ventricle was to be exposed. In four instances the chest wall was immediately closed without further operative procedure. In seven dogs the operation was extended to the pericardium and an incision made to the same extent as in the ligation experiments. Sterilized vaseline was applied between the visceral and parietal layers of the pericardium in three animals in order to prevent adhesions. The opening in the pericardium was sutured with plain catgut and the chest was closed in the usual manner. In the remaining twenty-six experiments a small vessel was ligated. The opening in the pericardium was made as nearly as possible over the point selected for the ligation and a silk ligature passed under the artery and periarterial structures. In the five instances in which a posterior division of the left coronary artery was ligated, the incision in the pericardium was made directly over the vessel in two and on the lateral aspect of the left ventricle in three.

One dog died from pneumonia and one from an intrapleural hemorrhage eight days following the operation. The remaining twenty-two animals were autopsied at chosen intervals from one to sixty-two days after the operation.

An electrocardiogram was taken prior to the anesthetic and at daily intervals following the operation. In the first eight experiments curves were taken after the anesthetic, and at frequent intervals during the first few hours after the operation. The anesthetic produced no significant alterations in the electrocardiogram. During the early post-

operative period, various types of arrhythmias were observed, and in a few an elevation of the T-wave was noted. The skin resistance was measured in each instance and never exceeded 2500 ohms.

A small twig of the anterior descending branch of the left coronary artery was ligated in eleven dogs. In one instance in which progress curves were taken at frequent intervals following the operation, an increase in the amplitude of the T-deflection was noted thirty minutes after the ligation. In another, Fig. 1, the T-wave in Leads I and II was negative within three hours. Within eighteen to twenty-four hours



A

Fig. 1.—Dog 2. *Operation:* Ligation of a small branch of the coronary artery on the anterior surface of the left ventricle. *Results:* Inversion of the T-wave in all leads followed by an increased amplitude and later by a return to the normal level. R-T segment elevated. *Pathology:* Twenty-nine days postoperative. Adherent pericardium, occlusion of a coronary vessel, and subepicardial fibrosis on the anterior surface of the left ventricle. Microscopic examination showed subpericardial fibrosis with extension into the adjacent myocardium.

a downward deflection of the T-wave in two or more leads was recorded in eight dogs. This alteration was possibly obscured in one instance by a persistent ventricular arrhythmia. In the remaining two animals there were no significant changes in the electrocardiogram. The location of the ligation and the leads in which the negative T-deflection occurred in the eight animals is shown in Fig. 2. It is to be noted that the T-wave was down in all leads in four, in Leads II and III in one, and in Leads I and II in three animals.

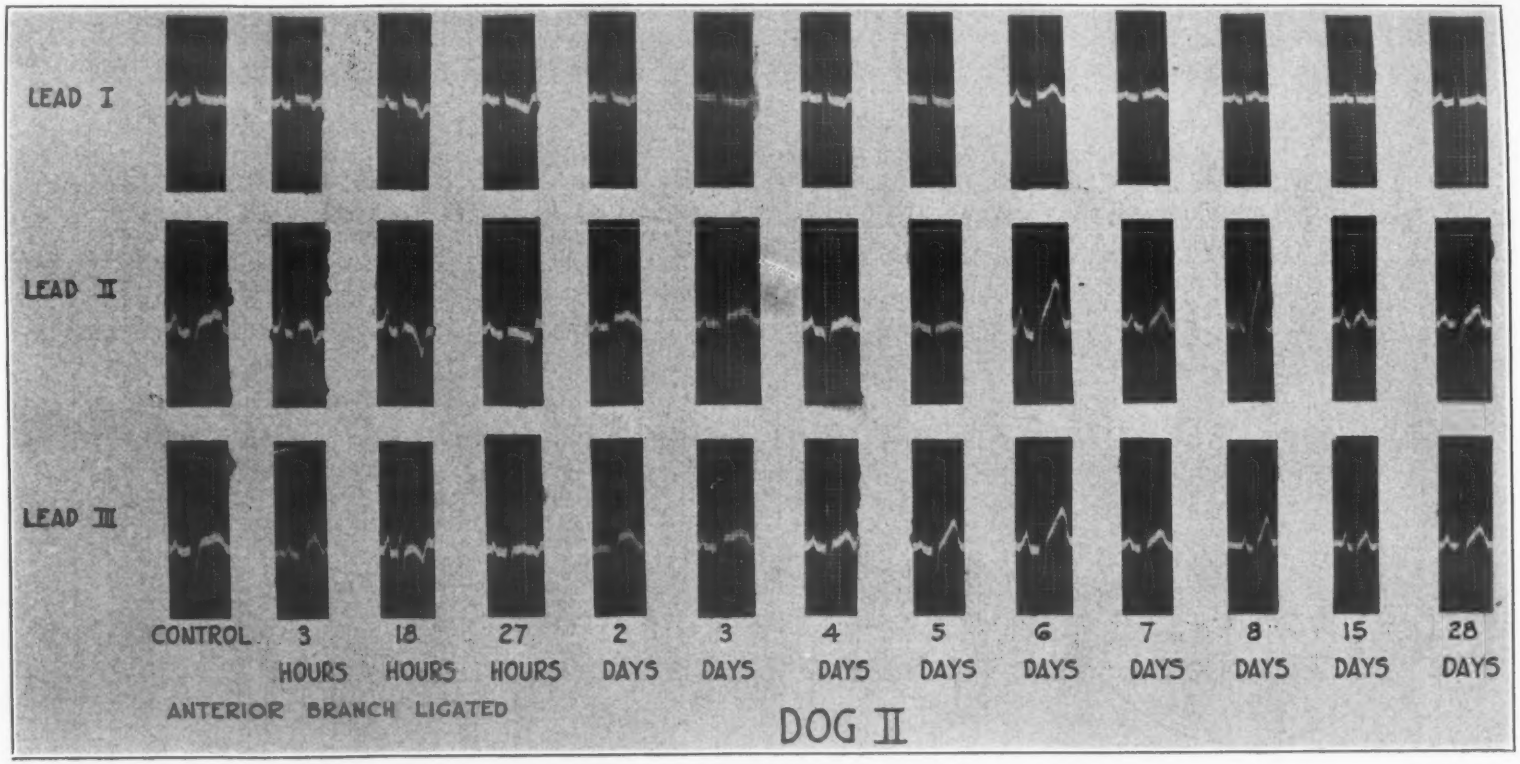
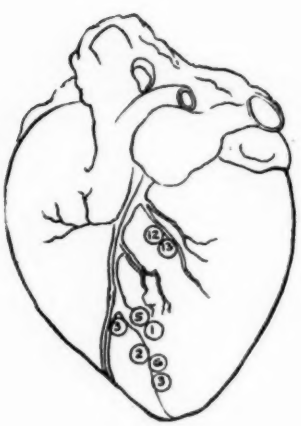
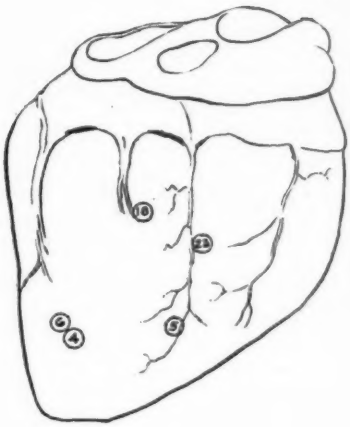


Fig. 1 *B*.—See legend under Fig. 1 *A*.



ANTERIOR

Fig. 2.

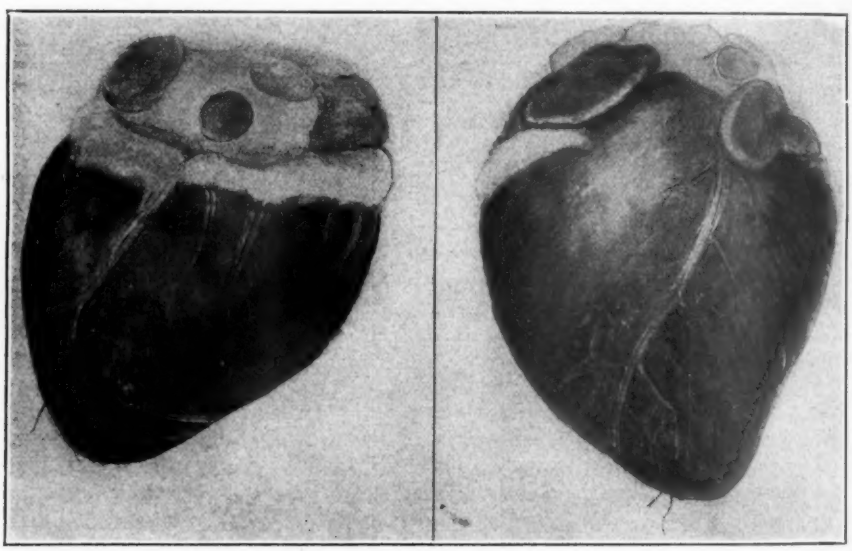


POSTERIOR

Fig. 3.

Fig. 2.—Anterior surface of left ventricle showing site of ligation for each animal. Inversion of T_1 and T_2 followed in Dogs 3 (twice) and 5. Inversion of T_2 and T_3 followed in Dog 12. Inversion of T_1, T_2, and T_3 followed in Dogs 1, 2, 6, and 11.

Fig. 3.—Posterior surface of left ventricle showing site of ligation for each animal. An inverted T-wave in all leads occurred in each instance.



A *B*

Fig. 4.—Dog 6. *First Operation:* Ligation of a small coronary vessel on the posterior surface of the left ventricle. *Result:* Inversion of T-wave in all leads with a high take-off of the R-T segment. *Second Operation:* Ligation of a small branch on the anterior surface of the left ventricle. *Result:* Inversion of the T-wave in all leads with an elevated R-T segment. *Pathology:* Seven days postoperative. Adherent pericardium over both ligations and occlusion of both vessels. Microscopic examination showed degeneration of the muscle fibers and partial replacement by connective tissue.

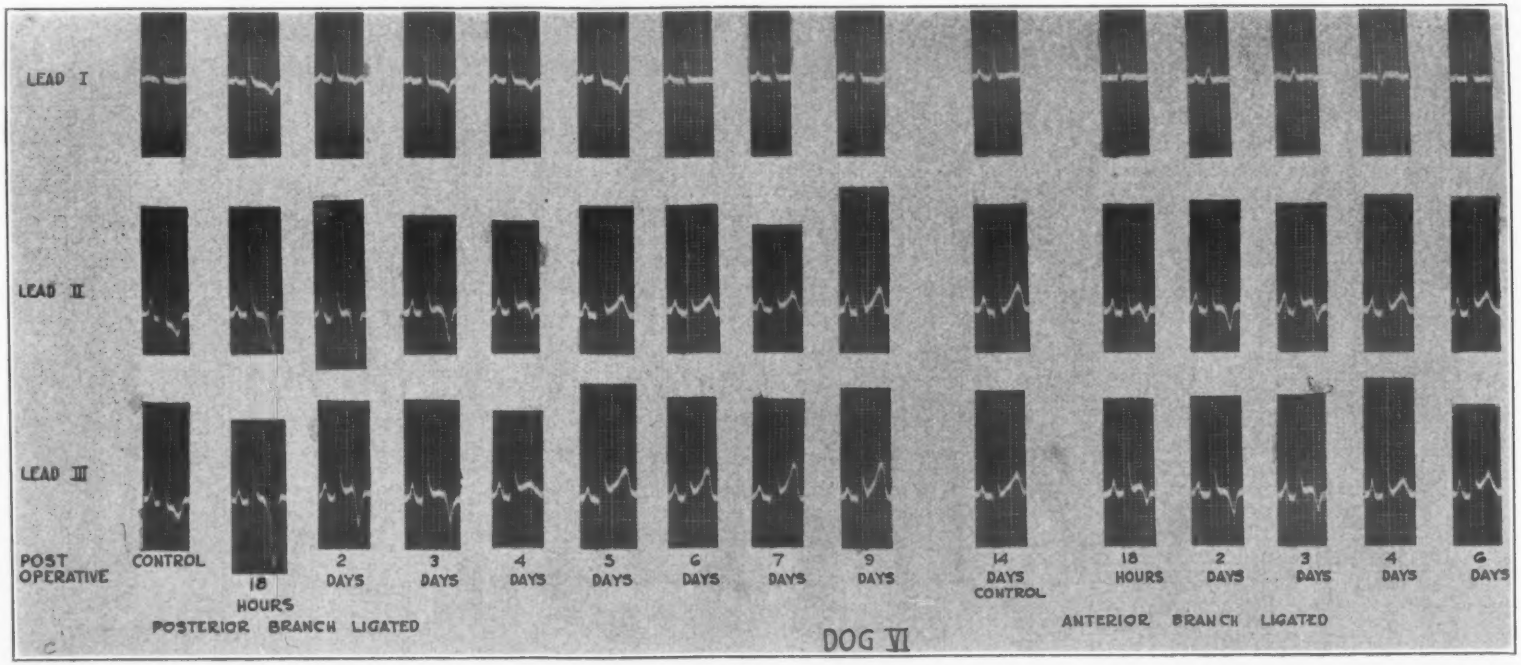
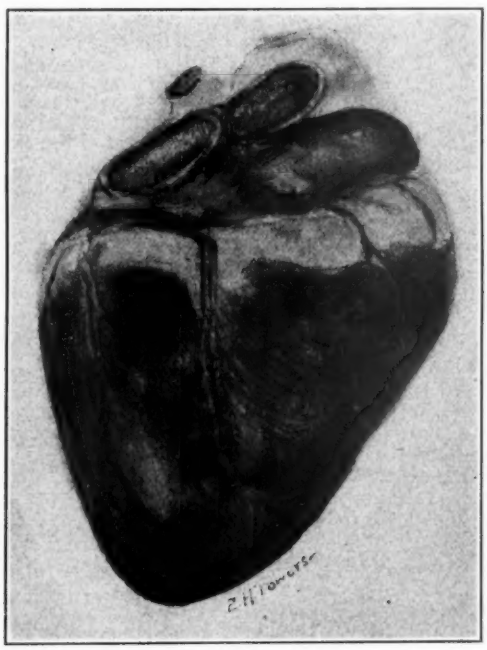


Fig. 4 *C*.—See legend under Fig. 4 *A* and *B*.

The T-wave usually returned to the positive phase in from four to six days. The change to the upright position was observed first either in Lead I or in Leads II and III. This was followed by a gradual increase in the amplitude of the T-deflection which reached the greatest height between the fifth and ninth day following the ligation, and gradually returned to the original level. The increase in the amplitude of the T-deflection was most prominent in Leads II and III, even though it was not always preceded by a negative phase in these particular derivations.



A

Fig. 5.—Dog 15. *Operation*: Ligation of small descending branch of coronary artery on right ventricle. *Result:* Inverted T-wave in Leads II and III, return to a positive phase on second day, followed by an increase in amplitude. R-T segment elevated. *Pathology:* Six days postoperative. Adhesions between pericardium and epicardium. Whitish discoloration of endocardium and small whitish areas in the myocardium below the ligation. Microscopic examination: Muscle bundles shrunken with loss of fibrillae and nuclei. Cytoplasm granular and vacuolated. Granulation tissue in epicardium.

A vessel was ligated on the posterior surface of the left ventricle in five dogs. These vessels were divisions of the circumflex branch of the left coronary artery. The ligation of these arteries produced the most constant change in the electrocardiogram, since in every instance a negative T-deflection in all leads was observed within eighteen hours (Fig. 3). The subsequent changes in the T-deflection after ligation of a posterior branch were identical to those following the ligation of the

divisions of the anterior descending branch of the left coronary artery. In three dogs the T-wave returned to the positive phase by the fourth day and the remaining animals were autopsied at twenty-four to forty-eight hours respectively after the operation in order to observe the pathological changes during this period of the T-wave negativity. In Fig. 4 it will be observed that after a period of fourteen days a vessel on the anterior apical surface of the left ventricle was ligated. The

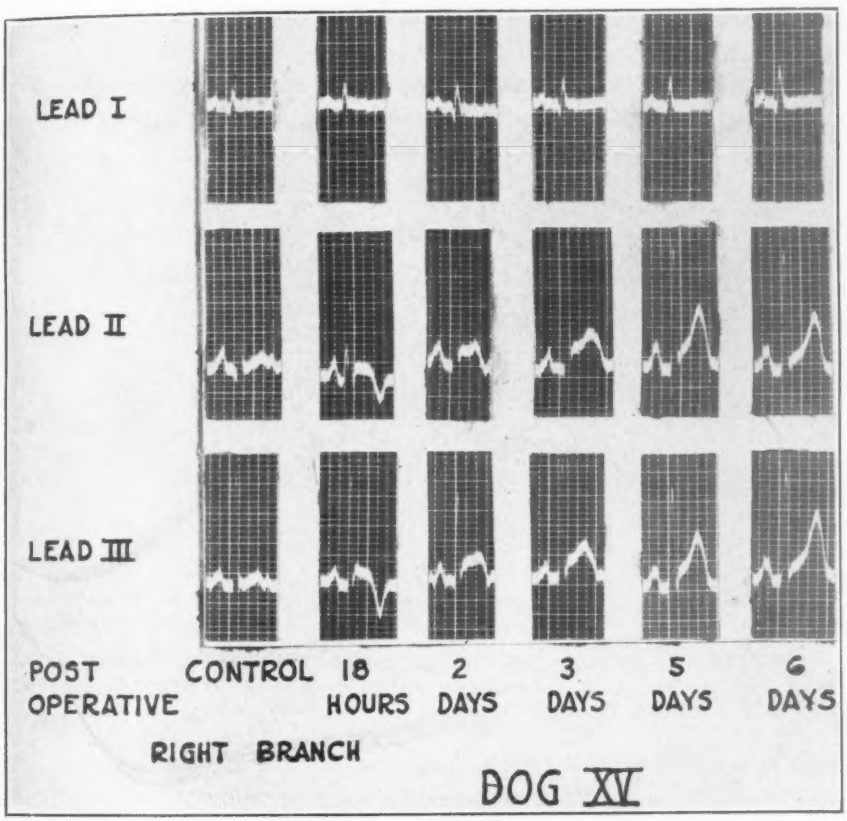


Fig. 5 *B*.—See legend under Fig. 5 *A*.

alteration in the T-wave following the latter ligation is of the same general character, but less marked.

In eight dogs a branch of the right coronary artery on either the anterior or lateral surface of the right ventricle was ligated. A negative T-wave occurred in seven dogs. This appeared in Lead I alone in four, and in Leads II and III in three (Fig. 5). These results seemed to differ from those observed following the ligation of the branches of the left coronary artery only in that the T-negativity was more frequently confined to Lead I, and under these circumstances persisted throughout the

period of observation. The location of the ligation and the changes in the T-wave associated with each are indicated in Fig. 6.

The pericardium was opened and sutured without the ligation of a vessel in seven dogs. A negative T-wave was reported in six and occurred in all leads in three animals (Fig. 7). Although the application of vaseline prevented the formation of adhesions between the layers of the pericardium, alterations of the electrocardiogram occurred. In all instances in which the animal was followed for any considerable period the electrocardiogram returned to normal as in the ligation experiments.

The chest wall was opened in four dogs without further operative procedure. In one instance the T-wave became negative in Lead I. This

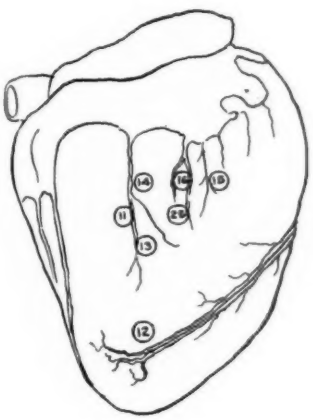


Fig. 6.—Right ventricle, showing site of ligation for each animal. Inversion of T_1 alone occurred in Dogs 11, 13, 14, and 16. Inversion of T_2 and T_3 occurred in Dogs 12, 15, and 25.

animal was autopsied on the fourth day and an extensive pericarditis was found. There were no significant electrocardiographic changes in the remaining three animals.

In those animals in which the pericardial sac was opened, but no vessel ligated, an inflammatory reaction of the visceral layer with a whitish discoloration of the underlying epicardium was found. Adhesions were present between the pericardium and the chest wall and between the pericardium and the epicardium in most cases. Even though there were no adhesions, the discoloration of the epicardium was a constant feature. The larger vessels passing through this area were patent in all instances.

On microscopic examination an inflammatory reaction was found in the pericardium and epicardium which extended into the superficial muscle tissue. The muscle cells in the involved area were lightly stained

and showed fragmentation and vacuolization. Varying degrees of cellular infiltration were present with some separation of the muscle fibers. There was also a marked hyperemia with an engorgement of the capillaries, and in certain instances hemorrhagic areas.

In the ligation experiments examination of the heart at necropsy showed that the vessel was occluded in every animal. The gross changes in the myocardium at the site of the infarction were usually slight and difficult to detect. In some there was no apparent alteration in the appearance of the cardiac musculature. Even in those instances in which gross changes were present it is extremely doubtful if many of the lesions would have been located had not the ligature directed attention to them. These lesions were usually limited to the central por-

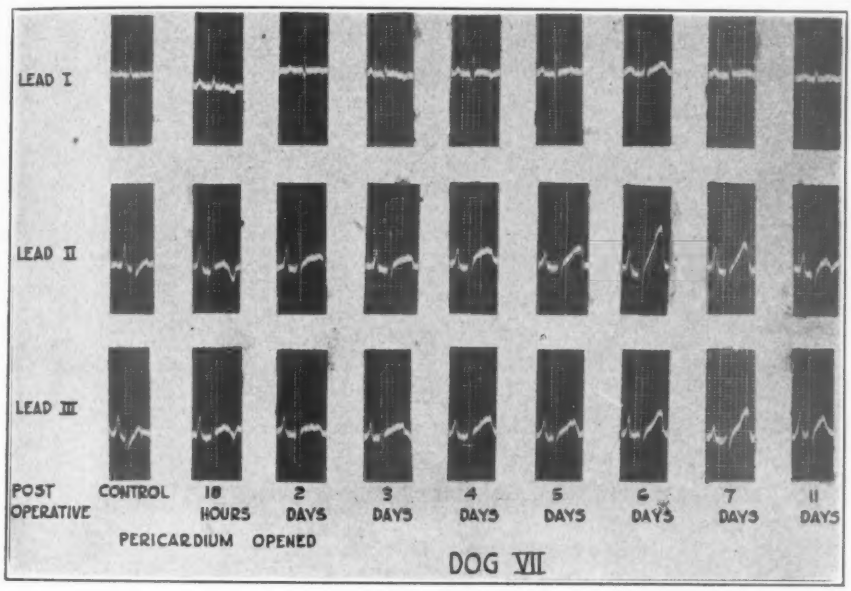


Fig. 7.—Dog 7. *Operation:* Pericardium opened and sutured without disturbing the myocardium. *Result:* Inversion of the T-wave in all leads with elevation of the R-T segment followed by an increased amplitude of the T-wave. *Pathology:* Eleven days postoperative. Thickened and adherent pericardium with the underlying vessels patent. Microscopic examination showed fusion of the pericardium and epicardium by connective tissue. The adjacent muscle cells stained poorly and contained vacuoles.

tion of the ventricular wall, but occasionally extended to the endocardium. In only one animal was there a distinct thinning of the ventricular muscle. The microscopic changes varied with the age of the lesion. In dogs autopsied twenty-four to forty-eight hours after the ligation, the histological changes were those of an acute degenerative process consisting of a loss of cellular outline and striations, indistinct nuclei, the presence of vacuoles in the cells and a cellular infiltration.

Fibrous tissue replacement generally began by the fifth to seventh day and was usually fairly completed by the end of the second or third week.

COMMENT

In the present investigation the changes in the T-wave were the most characteristic features. They occurred following the ligation of the smaller branches of the coronary arteries, after an incision in the pericardium, and in one instance subsequent to the opening of the chest wall alone. The various stages in the evolution of these alterations were associated with fairly definite pathological findings. Histological examinations during the period of negative T-deflection showed an acute degenerative lesion in the ligation experiments and an active inflammatory reaction in those in which an opening was made in the pericardium. When sections were made after the T-wave had returned to the positive phase or an exaggerated upright position, the histological picture was that of a healing process with fibrous tissue formation. The return of the electrocardiogram to the normal was associated with complete replacement by fibrous tissue.

It is to be noted from Figs. 2, 3, and 5 that there is no apparent correlation between the location of the lesion and the type of the electrocardiogram. In each instance in which a vessel was ligated on the posterior surface of the left ventricle, the T-wave became negative in all leads. The closure of a vessel on the anterior surface of the left or right ventricle might be followed by a negative T-deflection in all leads, in Leads II and III or on the right side in Lead I alone. In those in which the ligation of a posterior branch was followed after a period of two or three weeks by the closure of an anterior branch of the left ventricle there was no particular difference in the T-negativity except that it was more marked with the posterior lesion.

The changes in the R-T and the S-T segments were not a prominent feature. They occurred in the pericardial experiments as well as in those in which a vessel was ligated. When present they were invariably overshadowed by the alteration in the T-deflection and apparently dependent on the latter. Within recent years the alterations in the electrocardiogram associated with coronary occlusion have almost exclusively been referred to as an R-T deviation. In view of the findings in the dog where it is possible to follow each successive stage in the evolution of these changes we are not convinced that this is the correct interpretation. On the other hand, it would seem that the T-wave is primarily concerned and that the alterations in the R-T segment are secondary to the latter manifestations.

The alterations in the T-deflection, although less prominent and of shorter duration, were of the same general character, and the successive changes were identical to those described by Smith and later con-

firmed by various investigators of coronary occlusion. It is to be recalled that the lesions in the myocardium produced by the ligation of vessels in our experiments were very small and in certain instances not apparent in the gross specimen. Myocardial lesions were also demonstrated by the histological examination in each of the six animals in which alterations in the electrocardiogram occurred after an incision in the pericardium. In the one dog in which the T-wave changed to a negative deflection after the opening of the chest wall an extensive pericarditis was found at necropsy. While sections were not made of the heart in this particular instance, we are justified in assuming, in view of the findings in the other experiments, that the myocardium was involved. With this possible exception the successive changes in the T-wave were associated with a demonstrable lesion of the myocardium. It is believed that this type of electrocardiographic alteration is indicative of myocardial damage and that the changes observed by Barnes and Mann[7] after the opening of the pericardium, are explained on this basis. This is in accord with the observations of Porte and Pardee[21] with reference to rheumatic pericarditis and the conclusions of Cohn and Swift[24] and others concerning the alterations in the T-wave associated with rheumatic fever.

It would seem that the serial electrocardiogram, especially with reference to the successive alterations in the T-deflection, provides a means of detecting minor damage to the myocardium which might not be recognized otherwise. This is particularly applicable to coronary artery disease in which the progression of the cardiac disability is so frequently dependent on a series of coronary occlusions. If a larger vessel is occluded the clinical manifestations are often sufficient to permit a diagnosis. It is quite likely, however, that the closure of the smaller branches plays an important rôle in the progression of the cardiac disability in this form of heart disease and is often responsible for the anginal syndrome. While further detailed clinical studies may permit a diagnosis of certain of the occlusions involving the smaller branches, the possibilities in this direction are obviously limited. Our results have shown that the ligation of the smaller arterial twigs in the dog produce characteristic alterations in the electrocardiogram, and it is believed that the same will hold for man.

CONCLUSIONS

In the present investigation the occlusion of small branches of both the right and left coronary arteries and also the opening of the pericardium without the closure of a vessel produced successive changes in the T-wave of the electrocardiogram. In each instance the alteration in the T-deflection was associated with a lesion of the myocardium. We believe that electrocardiographic changes of this character are indica-

tive of a myocardial lesion and feel that these findings may be helpful in the diagnosis of occlusion of the smaller branches of the coronary arteries in man.

We wish to express our appreciation to Dr. W. W. Herrmann of the Department of Pathology for his examination of all necropsy specimens.

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STUDIES IN OSCILLOMETRIC PRESSURE*

H. R. Miller, M.D., and W. Chester, M.D.
New York, N. Y.

INTRODUCTION

THE oscillometric study of blood pressure is not new. As far back as 1880 Marey[1] noted that blood pressure oscillations are seen to be maximal when internal diastolic blood pressure is counterbalanced by an external pressure compressing the vessel. For the measurement of these excursions various instruments were soon invented, all based upon the use of external pressure applied through an armlet connected to a measuring indicator. Readings in pulsations (oscillations) were recorded graphically or visually. Visual recording devices were used by Hill and Barnard,[2] Oliver,[3] (using compressed air), Pachon,[4] and Stanton,[5] and Janeway[6] whose instruments were based on Gumprecht's[7] observations that the Riva Rocci sphygmomanometer could be utilized for this purpose. Graphic recording devices were employed by Gibson[8] (with Singer's modification), Recklinghausen[9] and Erlanger,[10] and recently a Pachon apparatus† has been modified to give graphic results.

These investigators were not in agreement on the relation of maximal oscillations to either systolic, diastolic or mean pressure.‡ Thus, for example, Hill and Barnard,[2] also Oliver,[3] fixed maximal oscillations as the mean pressure while Martin[11] confirmed this experimentally for an exposed artery lying on a firm flat surface but not in vivo under normal conditions. On the other hand Sahli,[12] Howell and Brush,[13] Oliver,[3] Gibson,[8] Pachon,[4] Recklinghausen,[9] Erlanger,[10] Janeway,[6] confirmed Marey's contention that maximal oscillation arose at the diastolic pressure level. Tschlenoff[14] expressed a view, discredited and neglected for a long time, that the maximal oscillations were associated with systolic pressure.

Recently Vaquez[15] and his coworkers turned to the question anew. They quote Pachon (1921) and Gley and Gomez (1930) who, in disproving Marey's principle, established maximal oscillations as agreeing with mean pressure. The Vaquez group now maintains unequivocally that maximum oscillations do not coincide with assumed diastolic pressure; instead they consider the maximum oscillations as a visual

*From the Montefiore Hospital, Medical Service of Dr. B. S. Oppenheimer.
†Manufactured by Boulitte and Co.
‡Mean pressure is not to be confused with pulse pressure. The difference between systolic and diastolic pressure is designated as pulse pressure; it represents the sudden increase in blood pressure as it distends an artery, the brachial, for instance, with each systole of the heart. Mean pressure, on the other hand, is estimated by taking the arithmetical mean of the systolic and diastolic figures. Lian (*Appariel Circulatiore*, Ed. 2, 1926) holds it more accurate to consider mean pressure as the sum of the diastolic figure and one-half the difference between the systolic and diastolic pressures.

registration at an optimum level of pressure of the largest fluctuations in intravascular pressure extant between two successive beats. According to Vaquez, this figure of the optimal level of blood pressure confusingly named "pression moyenne" (mean pressure) is an important index for studying vascular dynamics in health and disease. The French workers look upon it as a constant coefficient bearing no relation to the arithmetical mean pressure.

The purpose of our investigation was twofold: first, to note the occurrence of this phase of maximal oscillation during the cycle of pulse pressure changes, more especially placing it in its relation to diastolic, systolic, or mean pressure; second, to repeat the clinical application of oscillometric determinations, as carried out by Vaquez, in order to determine its clinical value. We used a Pachon apparatus, modified by Gallavardin to have two armlet cuffs and a simple mechanical device for releasing pressure in the armlet.

To clarify the discussion, we present Fig. 1 as a typical oscillometric record. With this as a basis we shall attempt to interpret the blood pressure excursions, correlating them with the dynamics of circulation.

PHYSIOLOGICAL CONSIDERATIONS

Fig. 1 exhibits vertical markings for the number of centimeters through which the Pachon oscillometer indicator moved at various levels of millimeter of mercury pressure, the latter being marked off on the horizontal base line. A superimposed upper curve represents a diagram of a usual radial pulse pressure graph and is seen to have its systolic point at 120 mm. of mercury, and its diastolic point at 60 mm. of mercury. A lower graph demonstrates that maximum oscillations took place at a level of 80 mm. of mercury.

The maximal oscillometric phase (MOP) is therefore 80.* If now we begin with the external pressure in the armlet cuff pumped up to 170 mm. of mercury, a level well above the systolic pressure in the brachial artery, it will be noted that no oscillations come through. This is so because the brachial vessel is completely obliterated and no pulsations are transmitted through its walls. At 150 mm. of mercury, however, the vessel has opened very slightly and the wall has begun to set up vibrations so that some oscillations are observed. The vessel continues to open, and its lumen now changes quite suddenly from a very narrow slit to a half closed shape. This abrupt transformation in contour is recorded as the systolic pressure, first, as a graphic angle, and second, by the appearance of a sound over the vessel. At this point or level of systolic pressure the external and internal systolic pressures are counterbalanced. The arterial wall, in this half closed

*This figure, i. e., 80 mm. of mercury, Vaquez would call "pression moyenne" (mean pressure). It has seemed to us less confusing to discard the term mean pressure in this connection and to look upon the figure of the level of blood pressure coincident with maximal oscillations as an index, the maximal phase or point in oscillations (MOP). This index is often a sharp peak but also not infrequently a plateau.

or flattened state of its lumen, continues to set up oscillations until a maximal phase, often a point, is reached, whereupon oscillations begin to diminish. Throughout this entire phase, it is important to realize that the lumen is half closed. With the continued drop in external compression, a point is reached where the vessel again undergoes an abrupt change, this time from a half closed to its full round circular shape. We have now reached the level of the disappearance of the systolic sound (diastolic pressure), and an angle is again registered

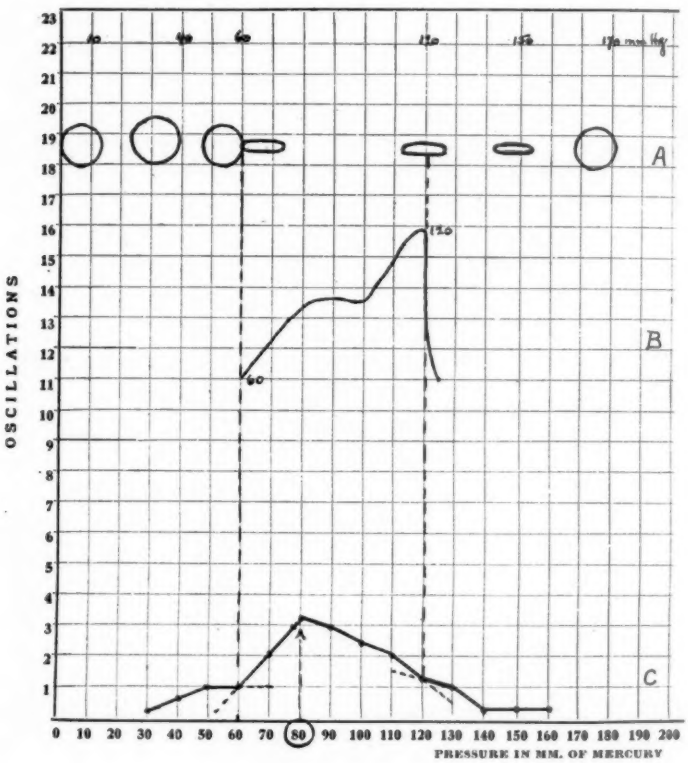

Fig. 1.—*A*, Cross-sections to show contour of brachial artery at various levels of mm. Hg pressure. *B*, Diagram of a radial artery pulse pressure graph. *C*, Graph of oscillometric excursions at various levels of mm. Hg pressure.

graphically. As external compression goes on falling, the vessel is seen to expand in its circular shape by its own diastolic pressure, and oscillations diminish and finally cease.

These lumen changes illustrated diagrammatically in Fig. 1 have actually been observed, and in the order and phases mentioned, by MacWilliam and Melvin,[16] who claim that the phase or point of maximal oscillations does not correspond to the level of diastolic pressure. They believe that maximal oscillations take place at an optimal moment during

the half closed position of the artery lumen and that the diastolic pressure is reached only after the maximal oscillometric phase has come and gone.

The recognition that the disappearance of the systolic sound marks the level of diastolic pressure was known to Korotkoff[17] but MacWilliam and Melvin definitely connected this auditory change with the abrupt visible transition in the contour of an arterial segment as seen by them through the transparent walls of an artificial compression chamber.

Although accepting and fully agreeing with auscultatory proof of the occurrence of diastolic pressure, Flack, Hill, and McQueen[18] raised strong objections to the interpretations of the experiments of MacWilliam and Melvin pertaining to the changes in the lumen where maximal oscillations are concerned. They urged that no account was taken of the rôle played by the vascular tissues and channels surrounding the brachial artery, for example, in maintaining and upholding diastolic pressure, and that the artificial model of MacWilliam and Melvin represented conditions observed only when a blood vessel is isolated under laboratory conditions or compressed against a flat hard surface, as bone. To overcome these objections, Flack, Hill and McQueen[19] constructed two compression chambers, one containing the blood vessel segment subjected to external pressures, the other designed to represent the resistance of the vascular tissues and venous pressure as they exist in vivo. With these chambers connected as one system they led a constantly increasing pressure into the venous channels. In a similar way they distended the artery segment with systolic pressure. They now observed in the latter a moment when the arterial wall could be flattened by external compression around the vessel, and this reading corresponded to the internal diastolic pressure in the artery. In other words, at diastolic pressure the artery was compressible, began to flatten slightly and to register pulsations which were maximal.

In the light of this apparent contradiction in interpretation concerning the relationship of diastolic pressure and maximal oscillations, we may say (1) that both groups of investigators are agreed upon the point designated as diastolic pressure according to the auscultatory method, and (2) that a study of our records of oscillometric determinations in 214 patients reveals that in human beings where no criticism can be leveled at the natural forces which cause and support diastolic pressure, we observed maximal oscillations not at the level of the disappearance of the systolic sound (diastolic pressure) but, as a rule, well above this level.*

*A point of interest is the fact that oscillations stay maximal sometimes over a plateau corresponding to a stretch extending over 20 to 30 mm. of mercury. This phase of maximal oscillations is often seen to be a peak at one particular point between the systolic and diastolic figures. In the Recklinghausen-Erlanger graphic registration, diastolic pressure is taken as that point characterized by a sudden diminution in maximum excursions. This point, however, is not always determinable because on occasions it may be impossible to obtain a sudden transition.

CLINICAL OBSERVATIONS

We studied 214 cases. Many patients were tested several times, and frequently the same patient was tested by different observers. With comparatively few discrepancies to be noted in the tables and text below and excepting the group of cases with marked myocardial damage on the basis of coronary artery disease, our observations in general are in accord with those of the Vaquez school. The exceptions are important, however, and will be discussed later.

Normal Cases.—We tested 56 normal patients, most of whom were young nurses or doctors. Twenty-seven patients ranged between eighteen and twenty-seven years of age; their MOP readings were either 80 or 90, occasionally 70 or 100; 8 patients ranged in age between thirty and thirty-eight years with MOP readings between 80 and 90; 3 patients, forty-one to forty-five years, had MOP figures of 80 to 90; 3 patients, ages fifty, fifty-one, fifty-three years respectively, had MOP

TABLE I

MISCELLANEOUS (NO HYPERTENSION)

NO.	SEX	AGE	MOP	SYSTOLIC	DIASTOLIC	
R6	M	60	80	110	75	Prostatic enlargement.
R7	F	75	100	150	90	Atherosclerosis.
R10	M	35	100	140	95	Lead poisoning.
R11	F	52	90	104	62	Anemia, parasites (intestinal).
R12	F	38	110	112	72	Cholecystitis.
R13	F	61	100	155	90	Retroperitoneal neoplasm.
R14	F	17	80	108	90	Ulcerative colitis.
R15	F	33	110	130	90	Duodenal ulcer.
R16	F	51	100	135	80	Cholecystitis, postoperative.
R17	F	59	90	124	68	Diabetes mellitus.
R8	M	53	100	130	90	Varicose veins.
R26	F	58	100	182	82	Emphysema.
R53	F	13	80	92	44	Diabetes mellitus.
3	F	72	110	112	58	Cachexia, arteriosclerosis.
6	F	60	100	128	60	Secondary anemia.
8	F	51	110	136	84	Diabetes mellitus, hepatomegaly.
17	F	42	90	140	80	Decompensated liver cirrhosis.
18	F	42	80	106	64	Decompensated liver cirrhosis.
26	F	21	90	90	58	Ulcerative colitis.
27	F	33	90	70	50	Ulcerative colitis.
123	F	67	80	124	64	Cystitis.
127	M	38	80	105	85	Bleeding duodenal ulcer.
129	F	43	110	124	84	Scleroderma.
7	M	65	80	138	84	Cholelithiasis (?) or coronary artery disease (?).
15	F	59	80	110	70	Cystitis, arthritis, coronary artery disease (?).
R65	M	22	120	92	62	Ulcerative colitis.
4	M		80	106	70	Congenital heart disease.
25	F	29	120	80	56	Patent ductus arteriosus, subacute bacterial endocarditis.
R9	M	31	100	150	82	Normal.
R2	F	58	100	150	90	Clinical angina pectoris.

figures of 90 to 100. One patient aged sixty years had an MOP reading of 80, and one aged eighty years had an MOP reading of 90.

Miscellaneous Group.—In the group of 30 patients with miscellaneous conditions (see Table I) and no hypertension, the MOP readings were normal in 23. Of the remaining 7 cases there were 5 (R12, R15, 3, 8, 129) who had a slightly elevated MOP, 110, and 2 cases (R65, 25) with the MOP at 120. In Case R65 only one reading was taken, and as there is no clinical evidence of hypertension, we are inclined to the possibility of a technical error as the cause of the high MOP. In Case 25 the MOP was verified on several different occasions and may be related to the pathological-physiological changes subsequent to the congenital defect. Case 3 was especially interesting because the patient was a little woman, aged seventy-two years, with marked emaciation and asthenia, whose weight declined to 56 pounds but whose MOP remained at 110.

TABLE II

RESPIRATORY CONDITIONS

NO.	SEX	AGE	MOP	SYSTOLIC	DIASTOLIC	HYPER-TENSION	
22	M	56	90	120	70	0	Chronic pulmonary tuberculosis, lung neoplasm.
28	F	58	110	94	72		Chronic pulmonary tuberculosis, hypertension 3 years ago.
29	F	27	100	85	55	0	Chronic pulmonary tuberculosis.
30	F	28	90	102	84	0	Chronic pulmonary tuberculosis.
31	M	25	80	100	70	0	Chronic pulmonary tuberculosis.
126	F	43	90	106	68	0	Lung neoplasm.
125	F	44	70	106	68	0	Pleurisy effusion.
124	F	36	80	118	65	0	Pneumonia.
20	M	57	90	110	80	0	Bronchitis, emphysema, bronchiectasis.
21	M	73	90	120	70	0	Bronchitis, emphysema, bronchiectasis, pneumokoniosis.
23	M	48	100	98	73	0	Bronchitis, emphysema, bronchiectasis.
2	M	26	110	104	70	?	Bronchial asthma.
			110	123	100		
105	M	17	90	120	70	0	Bronchial asthma.
107	M	46	100	110	70	0	Bronchial asthma.
108	M	38	100	138	80	0	Bronchial asthma.
110	F	50	100	126	70	0	Bronchial asthma.
111	F	34	90	120	85	0	Bronchial asthma.
113	M	27	100	110	76	0	Hay fever.
116	F	57	90	122	70	0	Bronchial asthma.
117	F	42	100	130	80	0	Hay fever.
1	F	21	120	120	70	+?	Bronchial asthma.
			90	108	80	+	
106	M	48	120	140	95	+	Bronchial asthma.
				130	90	+	
109	F	33	110	125	90	+?	Bronchial asthma. Myocardial damage.
112R	F	50	130	200	90	+	Bronchial asthma.
114	F	41	150	170	120	+	Bronchial asthma.
115R	M	63	200	220	130	+	Bronchial asthma.

Respiratory Conditions.—There were 26 cases in all (Table II). In 18 the MOP was normal but in 4 cases with associated hypertension the MOP was definitely elevated. In the remaining 4 cases the MOP was moderately elevated, 110 to 120. Analyzing these last 4 cases, we find that Case 28 with an MOP of 110 had had an antecedent hypertension. Case 109, with an MOP of 110, had suggestive clinical and electrocardiographic evidences of a recent coronary occlusion with a fall in blood pressure; yet the MOP remained at 110. The increased MOP in Cases 1 and 2 is difficult to explain. It varied on several different readings, only one being high in Case 1, while in Case 2 duplicate readings with slightly increased values were secured. Cases 1 and 2 received large quantities of adrenalin and ephedrine for some time, but we have no evidence that these drugs had any effect in altering the MOP readings.

Chronic Rheumatic Cardiovascular Disease.—Of 34 patients (Table III) in this group with one or more attacks of rheumatic activity, and with frank congestive failure at some time in the greatest number, only 4 had had hypertension (Cases 53, 57, 61, 74) and these 4 showed high MOP figures, i. e., from 120 to 170.

Table III also includes 20 instances of aortic insufficiency combined with mitral disease. In 2 of these (Cases R64 and 102) the MOP readings were slightly elevated despite the absence of hypertension. Subsequent oscillometric readings in R64 were always less than 100, although the original reading was 130, while in Case 102 the MOP remained at 110. We cannot explain this. In the remaining 18 patients, despite the greatly augmented pulse pressure, the diastolic pressure sometimes being at zero,* the MOP readings ranged between 80 and 90, occasionally reaching 70 or 60. This observation, previously reported by the Vaquez school, suggests that the MOP remains practically normal despite changes in pulse pressure and that the MOP and pulse pressure figures therefore cannot be identical.

A point of special interest in this connection is the comparison of the graphic, oscillometric, and the auscultatory methods for ascertaining diastolic pressure particularly in aortic insufficiency. With the auscultatory method, diastolic pressure is read at a low level, sometimes at the zero level of mercury. (Obviously diastolic pressure cannot be so low and support life.) With the oscillometric method, on the other hand, diastolic pressure is registered graphically as a terminal angle at a higher level (Fig. 1). This difference between the two methods suggests that the auscultatory method is misleading and that the systolic

*A further point of physiological and practical interest in connection with the mechanism of low diastolic pressure in aortic insufficiency relates to the explanation offered that the fall in diastolic pressure is due to regurgitant blood via the aortic orifice. This explanation is not entirely tenable because, as is well known, in cases of congenital ductus botalli with a small communicating opening where the escape of blood volume is small or negligible, diastolic pressure is liable to be quite low. Here as well as in aortic insufficiency, a loss of intravascular "head pressure" may be a responsible factor.

sound associated with aortic insufficiency remains audible long after the level of diastolic pressure has been passed.

Hypertension With Cardiovascular Disease.—The MOP readings were invariably greatly elevated in these 36 patients (Table IV) with hypertensive cardiovascular disease often associated with extensive atherosclerosis. In 8 patients with chronic glomerular nephritis and hypertension, the MOP readings ranged between 120 and 170. In two other instances of chronic glomerular nephritis (Cases 11 and 82) the MOP readings were conspicuously low, 100. One of these cases (11) never

TABLE III

CHRONIC RHEUMATIC CARDIOVASCULAR DISEASE

NO.	SEX	AGE	MITRAL	AORTIC	TRICUSPID	MOP	SYSTOLIC	DIASTOLIC	HYPERTENSION	
102	F	47	S&I	I		110	142	76	0	Epileptiform attacks.
34	M	10	S&I	I	I	90	124	40	0	
36	M	14	S&I	I	I	100	110	10	0	
33	M	14	S&I	I	I	90	94	66	0	
R64	M	18	S&I	I	?	130	100	70	0	Transient auricular fibrillation.
R52	F	13	S&I	I		70	130	0	0	
32	M	19	S&I	I		70	110	40	0	Subacute bacterial endocarditis.
35	M	12	S&I	I		90	110	10	0	
38	F	35	S&I	?		80	120	80	0	Hemiplegia.
39	M	19	S&I	I		90	130	40	0	
40	M	9	S&I	I		80	88	60	0	
41	M	15	S&I	I		70	120	50	0	
42	M	11	S&I	I		70	100	30	0	
43	F	6	S&I	I		90	120	50	0	
47	F	17	S&I	I		80	138	0	0	
94	M	47	S&I	I		60	110	25	0	
37						80	120	0	0	
95	F	18	S&I	I		100	110	60	0	
97	M	19	S&I	I		90	98	70	0	
99	M	14	S&I	I		90	130	0	0	
48	M	34	S&I	S&I		80	130	50	0	
45	F	47	S&I	?		100	125	72	0	
46		46	S&I	I		90	230	0	+	Chronic glomerular nephritis.
53	M	38	S&I	?		160	140	130	+	
						170	230	130	+	
R47	M	18	S&I	?		90	126	92	0	
R50	F	14	S&I			90	115	95	0	
R51	F	14	S&I			90	118	66	0	
100	M	19	S&I			100	130	85	0	
9	M	16	S&I			90	118	84	0	
16	F	29	S&I			90	80	50	0	
44	M	9	S&I			80	95	65	0	
57	M	53	S&I			135	164-120	120-58	+	Coronary artery disease.
61	M	36	S&I			120	138	96	+	Post scarlatinal nephritis.
74	F	44	S&I			130	168-100	94-72	+	Coronary artery disease (?).
101	F	14	I			90	116	80	0	Chorea.

had hypertension despite the presence of azotemia for several years; the other (82) had a very labile blood pressure, though at times a definite diastolic hypertension was present. There are also included in this group three cases with malignant nephrosclerosis who disclosed MOP figures of 160 to 180.

Coronary Artery Disease With Myocardial Damage.—This group of

TABLE IV

HYPERTENSIVE CARDIOVASCULAR DISEASE

NO.	SEX	AGE	MOP	SYSTOLIC	DIASTOLIC	
R	F	26	150	180	120	
R29	F	41	130	160	120	
R33	F	48	120	180	110	
R55	M	50	160	240	140	Friedrich's ataxia?
53	M	38	160	140	130	Chronic rheumatic cardiovascular disease, mitral lesion.
98			170	230	110	
54	F	36	120	180	100	Pluriglandular dyscrasia, diabetes mellitus, bronchitis, bronchiectasis.
57	M	53	120-130	128	72	Chronic rheumatic cardiovascular disease, myocardial damage.
58	F	62	180	280	100	Auricular fibrillation with regular ventricular rate.
60	M	49	140	160	100	Graves' disease—forme fruste.
			120	162	92	
67	F	68	130	150	75	Diabetes mellitus.
84	F	60	130	190	105	
86	F	42	120	130	90	Chronic pulmonary tuberculosis with antecedent hypertension.
88	M	47	170	190	120	
103	M	48	130	170	100	Luetic aortitis.
R54	M	60	115	110	80	Lues, antecedent hypertension.
R20	M	64	140	178	118	
R21	F	80	115	160	88	
R23	M	63	160	230	120	
R24	M	65	150	210	110	
R39	F	66	120	160	90	
R63	M	55	130	110	80	
68	F	58	170	246	94	
70	F	65	115	200	86	Diabetes mellitus.
71	F	62	120	230	110	
72	F	73	145	220	110	Arthritis, auricular fibrillation with regular ventricular rate.
80	M	59	140	188	116	
104	M	68	170	196	80	
85	M	33	160	190	110	Chronic pulmonary tuberculosis.
112	F	50	130	200	95	Bronchial asthma.
114	F	41	150	170	120	Bronchial asthma.
115	M	63	200	220	130	Bronchial asthma.
130	F	64	130	145	90	Lymphatic leucemia.
R5	F	59	160	160	96	
52	M	49	110	98	78	
				145	110	
77	M	84	120	150	48	Prostatic enlargement.
103	M	48	130	170	100	Luetic aortitis.

TABLE IV—CONTINUED

ADVANCED RENAL DISEASE

NO.	SEX	AGE	MOP	SYSTOLIC	DIASTOLIC	HYPERTENSION	
R8	F	25	170	220	165	+	Chronic glomerular nephritis, uremic.
R27	M	27	160	216	150	+	Chronic glomerular nephritis, uremic.
R49	M	50	130	168	104	+	Chronic glomerular nephritis, uremic.
R56	M	39	140	220	118	+	Chronic glomerular nephritis, uremic.
83	M	34	170	180	120	+	Chronic glomerular nephritis, uremic.
62		47	120	160	90	+?	Chronic glomerular nephritis, nephrotic phase.
65	M	44	120	140	92	+?	Chronic glomerular nephritis, nephrotic phase.
61	M	16	120	154	90	+?	Chronic glomerular nephritis, nephrotic phase.
11	F	16	100	134	70	0	Chronic glomerular nephritis, nephrotic phase.
82	M	35	100	130	100	+?	Chronic glomerular nephritis, nephrotic phase.
R57	M	22	180	210	140	+	Malignant sclerosis.
87	M	32	160	214	142	+	Malignant sclerosis.
R25	M	58	180	220	150	+	Malignant sclerosis.

33 patients (Table V) with coronary artery disease and in most instances showing corroborative electrocardiographic changes, is especially valuable in studying the clinical utility of the oscillometric method. Although the total number is small, these cases were carefully observed over a period of many months, a number coming to autopsy.

Coronary Artery Disease Without Hypertension (7 cases).—The MOP readings were normal in all cases. In 4 instances there had been a recent coronary artery occlusion.

Coronary Artery Disease With Hypertension (18 Cases).—In 14 instances in this group, the MOP readings were elevated. The remaining 4 cases (12, 49, 13, 10) had normal MOP readings. Of this latter group, in 3 instances (12, 13, 10) congestive failure was present at the time of the oscillometric determination.

Coronary Artery Disease With Known or Suspected Antecedent Hypertension (8 cases).—In 2 instances of known antecedent hypertension (137, 66) the MOP readings were 130 and 110 respectively. Both of these patients were in congestive failure. The remaining cases (78, 55, 5, 50, R69, 51) in which an antecedent hypertension was strongly suspected showed an elevation of the MOP readings to some degree. All but Case 51 presented evidence of congestive failure.*

At one time or another, therefore, manifestations of congestive heart failure were associated with persistent, known, or suspected antecedent

*In 2 instances (50, 137) the MOP readings were higher than the systolic blood pressure readings. This would appear to be impossible, but there is mention of this point in the literature by Flack, Hill and McQueen, and MacWilliam and Melvin, indicating that maximum oscillations may appear close to and even above the level of systolic pressure in certain pathological conditions of the arterial wall. Tschlenoff called attention to this clinically in 1905.

hypertension in the presence of normal or elevated MOP readings. These findings indicate that the maximal oscillometric phase bears no constant relationship to congestive failure.

TABLE V

CORONARY ARTERY DISEASE WITH MYOCARDIAL DAMAGE

NO.	SEX	AGE	MOP	SYSTOLIC	DIASTOLIC	HYPERTENSION	
R3	M	45	90	142	78	0	
R4	M	54	80	115	70	0	Very recent coronary occlusion.
R19	F	60	100	144	98	0	
R68	M	42	80	120	80	0	
14	M	71	80	120	70	0	Congestive failure.
19	F	70	90	140	75	0	Diabetes mellitus.
56	F	64	110	130	90	0	Hemiplegia.
10	M	68	90	150	60	+	Stokes-Adams syndrome, antecedent hypertension.
49	F	46	100	168-120	100-70	+	Diabetes mellitus, hemiplegia.
12	F	52	100	158- 94	110-60	+	Bundle-branch block.
78	M	56	110	148-110	100-80	+	
81	M	61	130	170-110	108-65	+	Bronchiectasis, polycythemia.
13	F	57	100	160-108	100-66	+	Diabetes mellitus.
R48	F	59	160	210-150	98-68	+	
R58	F	58	180	204-158	110-86	+	
R60	M	55	130	210	160	+	
R59	M	65	140	190	80	+	
64	M	56	140	160	96	+	Bronchial asthma.
69	F	54	160	190-114	104-70	+	Bundle-branch block.
73	F	45	150	190	100	+	
75	F	58	130	160- 70	102-45	+	
76	F	48	190	260	140	+	Diabetes mellitus.
79	M	45	150	170	120	+	Bundle-branch block.
57	M	53	135	164-120	120-58	+	Chronic rheumatic cardiovascular disease.
68	F	58	170	246	64	+	
137	M	48	130	120- 86	90-64	Antecedent	Ventricular aneurysm.
66	M	64	110	114- 80	85-50	Antecedent	Auricular fibrillation with regular ventricular rate.
78	M	56	115-120	138	85	Suspected	Arteriolarrenal disease.
55	M	66	120-130	140-134	80-78	Suspected	
5	F	63	100	162	70	Suspected	Arborization block.
R69	M	57	100-110	138-112	78-88	Suspected	
51	M	59	110	138	78	Suspected	Diabetes mellitus.
50	M	57	100-130	128- 80	92-64	Suspected	

SUMMARY

Oscillometric studies carried out on 214 patients revealed that the maximal oscillometric phase (the visual registration at an optimum level of the largest fluctuations in intravascular pressure between two successive beats) did not occur at the point of disappearance of the systolic tone (the diastolic pressure). The maximal oscillometric phase (MOP) was normal (80-100) in a group of normal cases as well as in practically all the cases in the miscellaneous and respiratory groups.

The MOP readings were definitely elevated in hypertensive cardiovascular disease.

In the instances of chronic rheumatic cardiovalvular disease, the MOP readings were within normal limits, except when associated with hypertension. In the subgroup with aortic insufficiency the MOP readings remained practically normal despite the low diastolic pressure.

In 33 cases of coronary artery disease with myocardial infarctions, 7 had normal MOP readings and had no hypertension. Among 18 instances with persistent hypertension the MOP readings were elevated in 14. In the remaining 8 cases, 2 had definite antecedent hypertension, and in 6 the clinical findings were very suggestive of antecedent hypertension. All 8 cases had elevated MOP readings.

Congestive failure appeared to have no constant relationship to the maximal oscillometric phase.

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THE COMBINED EFFECT OF EPHEDRINE AND ATROPINE ON COMPLETE HEART-BLOCK*

S. N. Cheer, M.D., C. L. Tung, M.D., and C. W. Bien, M.D.,
Peiping, China

THE use of ephedrine in complete heart-block was first reported by Miller[8] (1925) in a case of complete auriculoventricular dissociation with no history of Adams-Stokes' attacks. A moderate rise of blood pressure, an increase of auricular and ventricular rate, and a change in the shape of P-waves and ventricular complexes of the electrocardiogram were noted following the administration hypodermically of 100 mg. of ephedrine. Stecher[10] (1928) reported favorably the employment of ephedrine in a case of complete heart-block with syncope and convulsions due to ventricular standstill. Ephedrine was administered after barium chloride had failed to give complete relief. It was given by mouth in doses of 30 mg. three times a day for one week, followed by 20 mg. three times a day for two weeks. There was a complete absence of attacks during ephedrine therapy. The successful result in Stecher's case suggested a further study of the action of ephedrine in the presence of complete heart-block.

Two cases of complete heart-block without Adams-Stokes' syndrome were available for the study of the reaction to ephedrine and other drugs that are known to be beneficial in this condition. Studies on drugs other than ephedrine will be reported separately. The observations were made under controlled conditions. The patients were kept quiet in bed and undisturbed. Electrocardiograms were taken before and at frequent intervals after the administration by mouth of ephedrine. Blood pressure readings were made at frequent intervals and usually before the electrocardiograms, from which both auricular and ventricular rates were obtained.

Patient J. T. (Case 1) after 60 mg. of ephedrine in half an hour's time showed a rise of blood pressure from 138/54 to 142/64 mm. Hg, but practically no increase of ventricular rate which remained 40 to 41 per minute, although there was a decrease of auricular rate from 91 to 75 per minute (Table I). This slowing of auricular rate was due either to depressor nerve reflex effect from elevated blood pressure or to the stimulating effect of ephedrine on the parasympathetic nerve endings. There was no change in the ventricular complexes. Complete heart-block persisted and the difference between the P-P intervals associated with and those without ventricular contractions remained the same.

*From the Department of Medicine, Peiping Union Medical College, Peiping, China.

When a larger dose (120 mg.) of ephedrine was administered, there was a further increase in the blood pressure but mainly in the systolic level, from 106/52 mm. Hg before ephedrine to 168/64 mm. forty min-

TABLE I

CASE 1. EFFECT OF A SMALL DOSE OF EPHEDRINE ON COMPLETE HEART-BLOCK. THE PATIENT RECEIVED 1.6 GM. OF DIGITALIS AUG. 17 AND 18, AFTER THAT NO MORE DIGITALIS NOR ANY OTHER DRUGS, AUG. 25 EPHEDRINE, 30 MG. BY MOUTH AT 3:20 AND 3:50 P.M.

TIME	R-R, SEC.	P-P WITH QRS, SEC.	P-P WITHOUT QRS, SEC.	P-P AVERAGE SEC.	VENT. RATE PER MIN.	AUR. RATE PER MIN.	RATIO VENT.: AUR. RATE	B. P. MM. HG	REMARKS
3:18	1.500	0.56	0.66	0.61	40	98	1:246	138/54	Before ephedrine.
3:20									Ephedrine 30 mg.
3:30	1.470	0.62	0.64	0.63	40	95	1:230	138/54	
3:40	1.480	0.68	0.76	0.72	40	83	1:205	138/58	
3:48	1.460	0.84	0.88	0.86	40	70	1:175	140/64	
3:50									Ephedrine 30 mg.
3:55	1.470	0.72	0.76	0.74	40	81	1:198	142/60	
4:05	1.445	0.71	0.73	0.72	41	83	1:202	140/60	Complete block persists.
4:10	1.460	0.76	0.80	0.78	41	77	1:187	140/60	
4:15	1.450	0.70	0.80	0.75	41	80	1:192	140/56	No change of ventricular complex throughout the observation.
4:25	1.440	0.72	0.80	0.76	41	79	1:189	140/60	
4:35	1.510	0.76	0.84	0.80	40	75	1:189	142/64	

TABLE II

CASE 1. EFFECT OF A LARGE DOSE OF EPHEDRINE ON COMPLETE HEART-BLOCK, AUG. 27 EPHEDRINE 60 MG. BY MOUTH AT 10:00 AND 10:55 A.M.

TIME	R-R SEC.	P-P SEC.	VENT. RATE PER MIN.	AUR. RATE PER MIN.	B. P. MM. HG	REMARKS
9:30	1.450	0.750	41	81	106/52	Before ephedrine. Fig. 1.
10:00						Ephedrine 60 mg.
10:10	1.520	0.800	39	73	106/50	
10:20	1.540	0.790	39	76	116/46	
10:30	1.490	0.710	40	84	136/58	
10:50	1.370	0.745	43	81	154/58	Fig. 2.
10:55						Ephedrine 60 mg.
11:00	1.340	0.640	45	94	160/60	Rt. and left vent. extrasyst. Aberrant vent. complexes, occas. normal type.
11:15	1.340	0.640	45	94	160/66	
11:25	0.900	0.640	67	94	156/56	
11:35	0.850	0.680	70	91	168/58	Fig. 3.
11:45	0.840	0.600	71	100	168/62	Extrasyst. fewer.
12:00	0.870	0.620	69	97	168/62	Coupled rhythm, vent. extrasyst. regularly 0.62 sec. after normal form of vent. complex.
12:15	0.890	0.640	68	94	168/64	
12:40	1.150	0.600	52	100	130/50	Record in sitting position Fig. 4. Note disappearance of ventricular extrasyst. and aberrant ventricular complexes.

utes after the ingestion of the drug. There was also an increase of ventricular rate from 41 to 68 and of auricular rate from 81 to 100 per minute (Table II). A marked change in the ventricular rhythm and

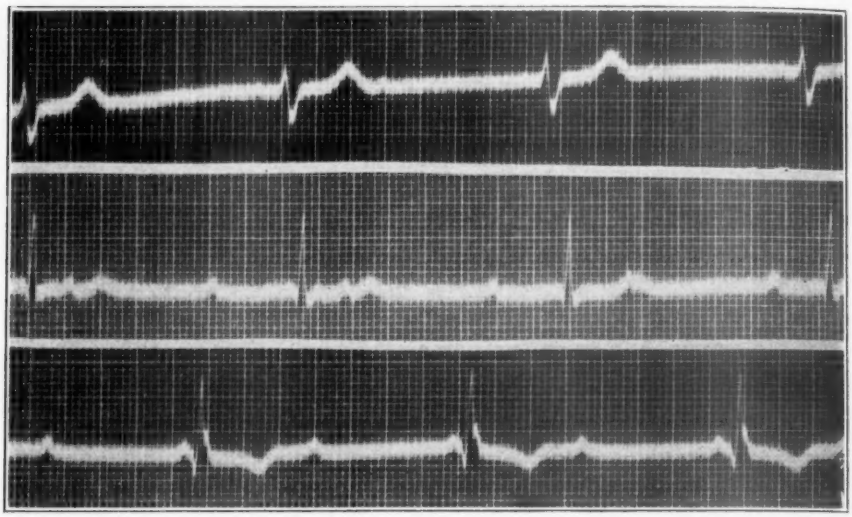

Fig. 1.—Case 1. See Table II. Electrocardiogram taken Aug. 27 at 9:30, before ephedrine. Ventricular complexes in Leads I and III are of aberrant type with S, tending to be deep. P-R intervals fairly regular, especially in Lead III, simulating two-to-one block.

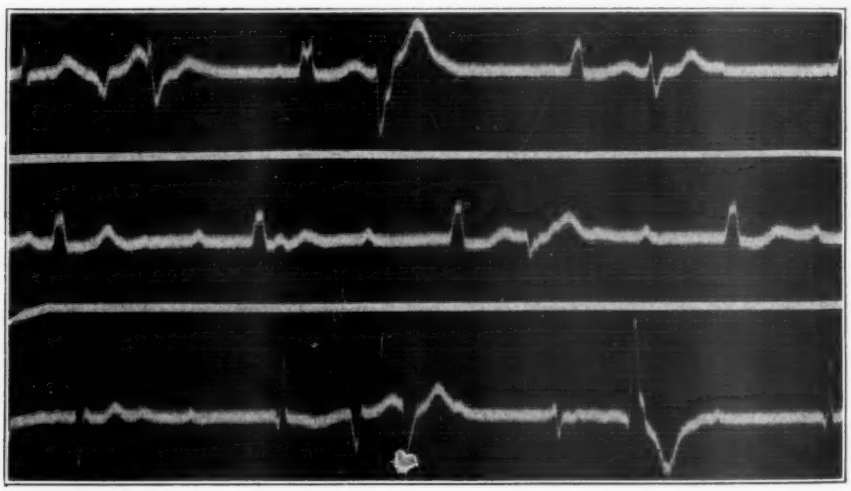

Fig. 2.—Case 2. See Table II. Aug. 27 at 10:50, fifty minutes after 60 mg. of ephedrine. Note the varied ventricular complexes extending to the form of complete bundle-branch block with intermediate types. The ventricular rhythm has become irregular and shows coupling due to right and left ventricular extrasystoles.

complexes was noted. The idioventricular rhythm became coupled or totally irregular, due to the presence of extrasystoles. The ventricular complexes of the idioventricular rhythm have the form of partial left

bundle-branch block. The extrasystoles occur at regular or irregular intervals, either alone or two or three together in succession. Their curves vary greatly, showing the forms of partial or complete bundle-branch block, possibly indicating the presence of several foci of origin. Possibly they represent reëntrant excitations. (Figs. 1 to 4.) In this patient the cardiovascular reaction to ephedrine was almost like that to epinephrine in regard to the fact that increase in the dosage of ephedrine resulted in a further increase of blood pressure; also in the fact that large doses of ephedrine caused a change in the ventricular complexes and appearance of many extrasystoles, which is the usual obser-

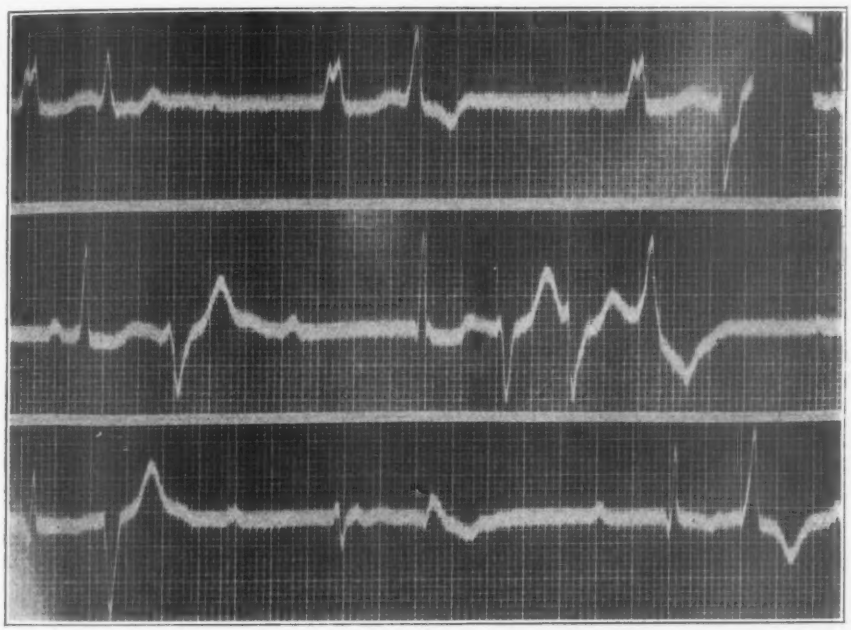

Fig. 3.—Case 2. See Table II. Aug. 27 at 11:35, twenty minutes after 120 mg. of ephedrine. Note abnormal ventricular complexes, especially in Leads I and III. The right bundle-branch type of ventricular complex present before ephedrine has changed to the left bundle-branch type. Ventricular rhythm interrupted by numerous right and left ventricular extrasystoles occurring singly or in groups.

vation after an effective dose of epinephrine, in the normal heart as well as in complete heart-block.

Patient C. K. T. (Case 2) did not show any marked pressor effect after the administration of either small or large doses of ephedrine. The results are presented in Tables III and IV. After 90 mg. of ephedrine in half an hour there was an increase of 2 ventricular beats per minute, from 37 to 39, and an increase of 15 auricular beats, from 95 to 111, and an increase of 5 mm. Hg in systolic and diastolic pressures (from 110/65 to 115/70). When the observation was repeated with a larger dose of ephedrine, 150 mg. in twenty minutes, there was no in-

crease in ventricular or auricular rate, but the same increase of 5 mm. Hg in systolic and diastolic pressures.

A marked variation in the pressor response to ephedrine such as seen in these two cases of complete heart-block is not an uncommon occurrence in individuals with normal hearts (Miller,[8] 1925, Rowntree and

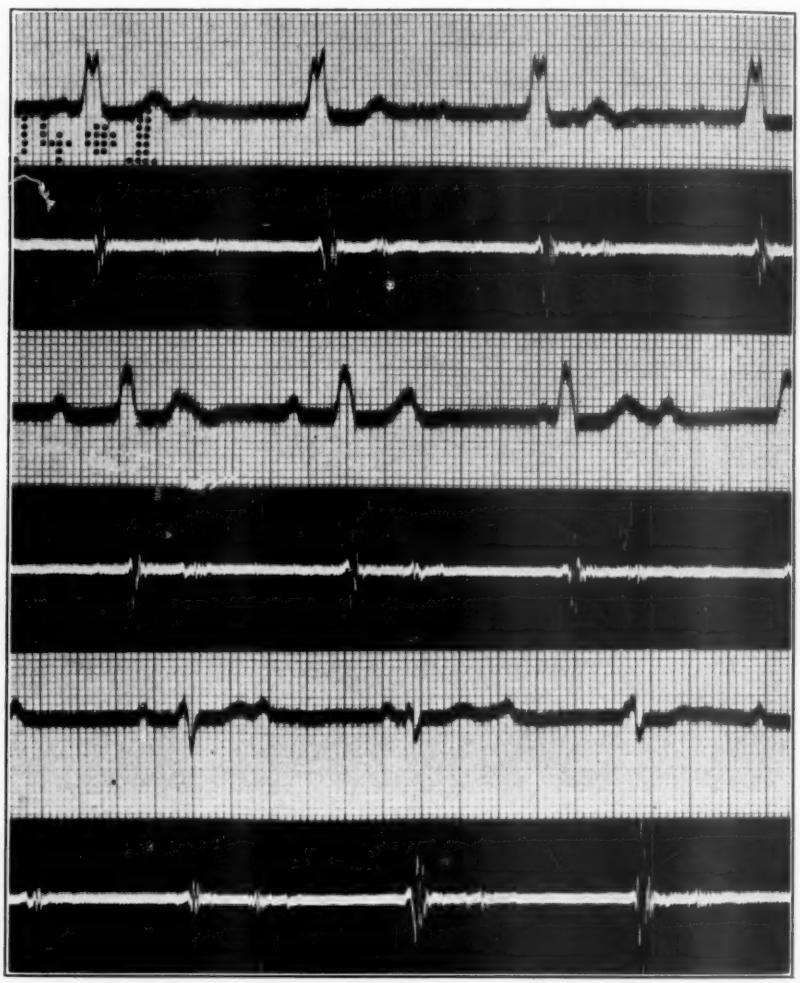

Fig. 4.—Case 2. See Table II. Aug. 27 at 12:40, in sitting position, one hour forty-five minutes after ephedrine, 120 mg. Note the disappearance of ventricular extrasystoles after slight exertion from lying to sitting position. Normal form of QRS no longer seen. The curves suggest left bundle-branch block.

Brown,[9] 1926, etc.) and is more frequently encountered in asthmatic patients (Thomas,[11] 1926, Chen,[1] 1927, etc.). The explanation for the variation perhaps involves factors which are also responsible for most, if not all, of the differences in the effect upon cardiac rate. We found, however, no correlation between the rise of blood pressure and the in-

crease of auricular or ventricular rate in our cases. In Case 2 (Table III) after 90 mg. of ephedrine, the increase of auricular rate was out of proportion to the increase of blood pressure, while in Case 1 (Table I) after 60 mg., the rise of blood pressure was greater than the increase of auricular or ventricular rate. Kreitmair[6] (1927) explained the dif-

TABLE III

CASE 2. EFFECT OF A SMALL DOSE OF EPHEDRINE ON COMPLETE HEART-BLOCK, SEPT. 14 EPHEDRINE 30 MG. BY MOUTH AT 9:12, 9:34, AND 9:54 A.M.

TIME	R-R SEC.	P-P SEC.	VENT. RATE PER MIN.	AUR. RATE PER MIN.	B. P. MM. HG	REMARKS
9:10	1.630	0.630	37	95	110/65	Before ephedrine.
9:12						Ephedrine 30 mg.
9:22	1.640	0.620	37	97	110/65	
9:32	1.650	0.620	36	97	110/65	
9:34						Ephedrine 30 mg.
9:42	1.650	0.620	36	97	115/70	
9:52	1.620	0.590	37	98	115/70	
9:54						Ephedrine 30 mg.
10:02	1.575	0.570	38	105	115/70	
10:12	1.565	0.550	38	110	115/70	Complete block persisted.
10:22	1.530	0.550	39	110	115/70	No change of ventricular complex throughout the observation.
10:32	1.515	0.540	39	111	115/70	
10:52	1.505	0.610	40	98	110/70	

TABLE IV

CASE 2. EFFECT OF A LARGE DOSE OF EPHEDRINE ON COMPLETE HEART-BLOCK, SEPT. 16 EPHEDRINE 90 MG. BY MOUTH AT 10.30 A.M. AND 60 MG. AT 10:50 A.M. A TOTAL OF 150 MG. IN TWENTY MINUTES

TIME	R-R SEC.	P-P SEC.	VENT. RATE PER MIN.	AUR. RATE PER MIN.	B. P. MM. HG	REMARKS
10:28	1.555	0.660	38	91	110/70	Before ephedrine.
10:30						Ephedrine 90 mg.
10:40	1.565	0.730	38	82	110/70	
10:48	1.570	0.600	38	78	110/70	
10:50						Ephedrine 60 mg.
11:00	1.580	0.755	38	80	110/75	Complete block persisted.
11:10	1.590	0.720	38	83	115/21	No change of ventricular complex.
11:20	1.600	0.750	37	80	115/75	
11:30	1.580	0.740	38	81	115/75	
11:50	1.575	0.760	38	79	115/75	
12:00	1.570	0.760	38	79	115/75	
12:10	1.580	0.770	38	78	115/75	

ference of pressor effect on the basis that small doses of ephedrine stimulate the sympathetic nerve endings, while large doses stimulate the parasympathetic endings.

Chen and Schmidt[3] (1924) found that large doses of ephedrine depress the heart. In our cases the response to the same large dose varied. In Case 1 there was a marked pressor response and in Case 2

practically none. The actual dose may have been still "small" for Case 1, although it was "large" for Case 2, so that the absence of any appreciable pressor effect in Case 2 may be the result of depression of the heart. Another possible explanation involves limitation of the number of "receptors" in Case 2, a theory advanced by Chen and Meek[2] (1926). In animal experiments the depressant action of ephedrine on the heart is not antagonized by atropine according to Kreitmair[6] (1927) and Fujii[5] (1925). Chen and Meek[2] (1926) found vagotomy or

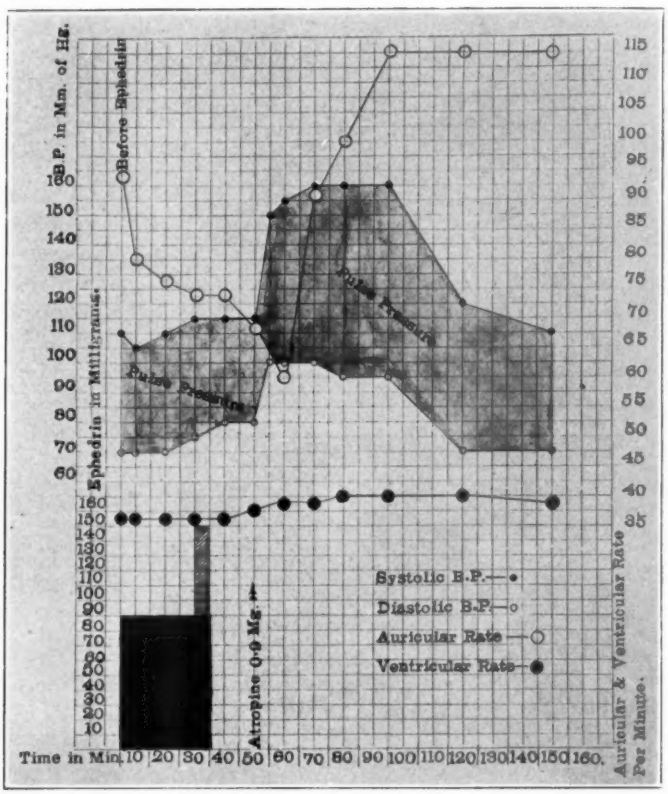

Fig. 5.—Combined effect of ephedrine and atropine one a case of complete heart-block.

atropinization did not affect the rise of blood pressure in dogs. On the other hand Mehes and Kokas[7] (1929) believed that the depressant effect was partly removed by atropine.

To test the validity of these hypotheses in the clinical case, atropine was given in Case 2 after the patient had received ephedrine. The results are shown in Fig. 5 and Table V.

With regard to the pressor effect the results were as follows. Half an hour after the patient had received 150 mg. of ephedrine by mouth, he was given hypodermically 0.9 mg. of atropine. Two minutes after

the atropine there was a sudden rise of blood pressure from 115/80 to 150/100 mm. Hg. This elevation of blood pressure reached its maximum (160/100) in twenty minutes. The diastolic pressure began to fall before the systolic pressure. It dropped to 95 and 70 mm. Hg at thirty and seventy minutes respectively after atropine. The pressure returned to its original levels (110/70) only at the end of one hour and forty minutes, when the auricular rate was still increased. The elevation of blood pressure occurred before the increase of auricular or ventricular rate and was rather sudden. The fall was also somewhat abrupt and the

TABLE V

CASE 2. COMBINED EFFECT OF EPHEDRINE AND ATROPINE ON COMPLETE HEART-BLOCK, EPHEDRINE 90 MG. BY MOUTH AT 9:10 A.M. AND 60 MG. AT 9:32 A.M., ATROPINE 0.9 MG. HYPODERMICALLY AT 10:02 A.M.

TIME	R-R SEC.	P-P SEC.	VENT. RATE PER MIN.	AUR. RATE PER MIN.	B. P. MM. HG	REMARKS
9:08	1.585	0.640	37	94	110/70	Before ephedrine.
9:10						Ephedrine 90 mg.
9:20	1.590	0.750	37	80	105/70	
9:30	1.610	0.780	37	77	110/70	
9:32						Ephedrine 60 mg.
9:40	1.605	0.810	37	74	110/75	
9:50	1.590	0.810	37	74	115/80	
10:00	1.565	0.870	38	69	115/80	
10:02						Atropine 0.9 mg. hypodermically.
10:05					150/100	
10:10	1.530	1.000	39	60	155/100	Complete block persisted.
10:20	1.515	0.680	39	94	160/100	No change of ventricular complex. No extrasystoles.
10:30	1.495	0.600	40	100	160/95	
10:45	1.495	0.520	40	115	160/95	
11:10	1.505	0.520	40	115	120/70	
11:45	1.510	0.520	39	115	110/70	

duration of the elevation was much shorter than that produced by ephedrine alone. Thus atropine appears to hasten and to intensify the pressor effect of ephedrine, but shortens the duration. This combined action of atropine and ephedrine is not synergy in the strict sense of the word. It suggests that atropine neutralizes the parasympathetic effect which results either from the individual's vagotony or from the stimulating action of ephedrine on parasympathetic nerves. If the lack of pressor effect after therapeutic doses of ephedrine is due either to a limited quantity of "receptors" or to depressant action of ephedrine as suggested by Chen, then atropine must increase, if not in amount at least in sensitivity, these "receptors" or it must abolish the depressant action of ephedrine on the human heart.

As to the effect on auricular and ventricular rate, after ephedrine and before atropine there was a decrease of auricular rate from 94 to 69 per minute, which persisted even ten minutes after atropine (when the

auricular rate was 60 per minute), while the ventricular rate remained constant. According to Chen and Schmidt (1924) and Chen and Meek (1926) after therapeutic doses of ephedrine pulse rate is usually slowed, occasionally accelerated. They explained the bradycardia as a reflex effect of the rise of blood pressure. In complete heart-block the vagus usually exerts little or no influence on the idioventricular rhythm but retains its control of the auricles; while the ventricles are under the influence of the sympathetic nerves. The primary slowing of auricular rate after ephedrine with practically no elevation of blood pressure in this patient would appear to be due to stimulation of the parasympathetic nerves rather than to a depressor reflex effect. The ventricles are not affected, because they are not under the influence of the vagus. About ten minutes after atropine there was a marked rise of blood pressure and a further slowing of the auricular rate (from 69 to 60 per

TABLE VI

CASE 2. EFFECT OF ATROPINE ON COMPLETE HEART-BLOCK, ATROPINE 2 MG. HYPODERMICALLY AT 9:15 A.M.

TIME	R-R SEC.	P-P SEC.	VENT. RATE PER MIN.	AUR. RATE PER MIN.	B. P. MM. HG	REMARKS
9:10	1.680	0.860	36	70	110/70	Before atropine.
9:15						Atropine 2 mg.
9:25	1.655	0.740	36	81	100/70	
9:35	1.670	0.600	36	100	90/65	Complete block persisted.
9:55	1.720	0.610	35	98	90/65	No change of ventricular complex.
10:15	1.770	0.610	34	98	100/70	
10:45	1.795	0.650	34	92	100/70	

minute). This later auricular slowing is apparently the result of a depressor reflex effect from elevated blood pressure. At the height of the atropine effect the auricular rate increased to 115 per minute in spite of the elevated blood pressure (160/95 mm. Hg). So it seems that the depressor reflex effect on the auricular rate was abolished by atropine. There was practically no change in the ventricular rate after 150 mg. of ephedrine, but an increase of three beats at the height of the atropine effect.

As to the electrocardiographic curves there was no change in the shape either of the ventricular complexes or of the P waves. Complete heart-block persisted. No complaint came from the patient during the course of the observations. His face was noticed to be slightly flushed at the height of the reaction.

In order to exclude in this patient a possible abnormal reaction to atropine, 2 mg. were given hypodermically with no other medication. The results are presented in Table VI. At the height of the effect there was a fall of blood pressure from 110/70 to 90/60 mm. Hg. One and a

half hours later, the ventricular rate showed a slight decrease, from 36 to 33 per minute, and the auricular rate increased from 70 to 92 per minute. Evidently this patient reacted to atropine as usual.

To determine whether or not a similar action of atropine occurs in combination with pseudoephedrine, the following observations were made. Half an hour after the patient C. K. T. (Case 2) had received 150 mg. of pseudoephedrine by mouth, 0.9 mg. of atropine was administered hypodermically. The results are given in Table VII. There was no effect on the blood pressure except that the diastolic pressure increased slightly, from 65 to 70 mm. Hg for a very short time. The ventricular rate remained the same, but the auricular rate began to increase at twenty minutes after atropine and remained elevated even to

TABLE VII

CASE 2. COMBINED EFFECT OF PSEUDOEPHEDRINE AND ATROPINE ON COMPLETE HEART-BLOCK, PSEUDOEPHEDRINE 90 MG. BY MOUTH AT 9:55 AND 60 MG. AT 10:17 A.M., ATROPINE 0.9 MG. HYPODERMICALLY AT 10:49 A.M.

TIME	R-R SEC.	P-P SEC.	VENT. RATE PER MIN.	AUR. RATE PER MIN.	B. P. MM. HG	REMARKS
9:50	1.615	0.780	37	77	100/65	Before pseudoephedrine.
9:55						Pseudoephedrine 90 mg.
10:05	1.650	0.830	36	72	100/65	
10:15	1.660	0.800	36	75	100/65	
10:17						Pseudoephedrine 60 mg.
10:25	1.670	0.830	36	72	100/65	
10:35	1.680	0.930	36	65	100/65	
10:45	1.700	0.810	35	74	100/65	
10:49						Atropine 0.9 mg.
10:50	1.690	0.900	35	67	100/65	Complete block persisted.
11:00	1.655	0.840	36	71	100/65	No change of ventricular complex.
11:10	1.660	0.620	36	97	100/65	
11:20	1.660	0.570	36	105	100/65	
11:30	1.660	0.560	36	107	100/70	
11:50	1.690	0.620	35	97	100/70	
12:10	1.705	0.620	35	97	100/65	

one and a half hours later. Pseudoephedrine, therefore, seems not to act in combination with atropine as does ephedrine.

Unfortunately the patient J. T. (Case 1) left the hospital before there was an opportunity to study his reaction to atropine and ephedrine in combination. Three individuals with normal hearts were studied and found to have the same reaction as the patient C. K. T.

Chen and Schmidt[4] (1930) in their recent review of ephedrine stated that the influence of atropine upon the cardiac effects of ephedrine in man apparently had not been investigated. Our results suggest that atropine either abolishes the depressant action of ephedrine on the heart in man or neutralizes the vagotony of the individual or the parasympathetic stimulation of ephedrine, thus permitting the ephe-

drine to stimulate freely the sympathetic nerve endings. The degree of pressor effect and the duration of the cardiac cycle after certain doses of ephedrine in combination with atropine are the total result of their balanced action on sympathetic and parasympathetic nerves.

SUMMARY

1. Two cases of complete heart-block responded to ephedrine quite differently. (a) With a small dose of ephedrine, Case 1 showed practically no change in auricular or ventricular rate, but a moderate elevation of blood pressure. In Case 2 there was an increase of auricular rate, but practically no change in ventricular rate or blood pressure. (b) With a large dose of ephedrine Case 1 showed an increase of auricular and ventricular rate and a marked elevation of blood pressure. The ventricular complexes varied and there were frequent ventricular extrasystoles. In Case 2 there was a decrease in auricular rate while the ventricular rate remained constant. There was practically no pressor response, and no change in the electrocardiograms.

2. In instances in which slowing of the auricles occurred without any appreciable elevation of blood pressure, the slowing may be ascribed to the stimulating effect of ephedrine on the parasympathetic nerves.

3. When an effective dose of atropine was administered to an ephedrinized patient with complete heart-block, a marked increase of auricular rate and a slight elevation of ventricular rate with a marked elevation of blood pressure and increase of pulse pressure occurred. This action of ephedrine in combination with atropine suggests that atropine neutralizes the parasympathetic effect that results either from the individual's vagotony or from the stimulating effect of ephedrine on the parasympathetic nerves.

4. Atropine hastened and intensified the pressor effect of ephedrine but shortened its duration, and abolished the depressor reflex effect of high blood pressure on the auricular rate.

5. No corresponding effect was noticed when atropine was combined with pseudoephedrine.

6. Ephedrine and ephedrine in combination wifh atropine did not abolish the complete block.

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A CLINICAL STUDY OF RESPIRATORY VARIATIONS IN THE FORM OF THE ELECTROCARDIOGRAM*

LEWIS W. WOODRUFF, M.D.
JOLIET, ILL.

VARIATIONS in the height of the various waves of the electrocardiogram, especially the QRS wave, have been universally recognized since 1910, when Einthoven first described them. Numerous articles on this subject have appeared since that time, principally by Lewis, Wenckebach, Winterberg and Gebert and Grosser. The commonly accepted explanation for this phenomenon has been that it is due to a shifting of the electrical axis as a result of changes in the position of the heart, which are mainly produced by movements of the diaphragm. Recently Condorelli[1] presented a number of clinical and experimental electrocardiograms showing marked respiratory changes, which were obviously not due to mechanical shifting of the heart's axis and yet were not conclusively proved to be due to vagal or sympathetic influence.

Although much has been written on this subject, as yet very little attention has been given to variations in the form of the electrocardiographic waves, that is, changes in a slurred or notched QRS or P-wave occurring with respiration. In a review of the literature several instances were found bearing on this particular phenomenon. Hochrein[2] described a case in which the electrocardiogram after an attack caused by coronary thrombosis showed a striking variation in the height and form of the R-wave synchronous with respiration, a change which previously had not been observed. In fact the majority of the tracings of the rest of his patients with myocardial infarction presented this finding. An explanation according to the idea of Hering was given, namely, that with the venous hyperemia which follows coronary thrombosis an increase in vagus tone is produced.

Also Hallermann,[3] who wrote concerning the clinical significance of small ventricular excursions in the electrocardiogram, was able to show that these changes are related to disturbances in the coronary circulation. The characteristic curves published by him all show respiratory form changes, although the author did not discuss their clinical significance.

In an article on the significance of a large Q-wave in Lead III Pardee[4] presented one case of a splintered QRS wave in Lead III, whose form changed definitely with the phase of respiration. Winternitz, in a discussion of Condorelli's[1] work, showed an electrocardiogram in which a complete shift from a left bundle-branch block in inspiration to a right bundle-branch block in expiration occurred. He believed that this

*From the Medizinische Universitätsklinik, Leipzig, Germany (Director, Prof. Dr. Morawitz).

striking change must have been due to a shifting of the electrical axis produced by diaphragmatic movements, rather than by vagal or sympathetic influence, since the administration of atropine and pressure over the carotids were without effect.

A large supply of material for the clinical study of these phenomena was offered me in the medical division of the University of Leipzig, where for the year April, 1930, to April, 1931, tracings from some 2000 patients were recorded. These consisted of the simultaneous registration of electrocardiograms and respiratory curves. The electrocardio-

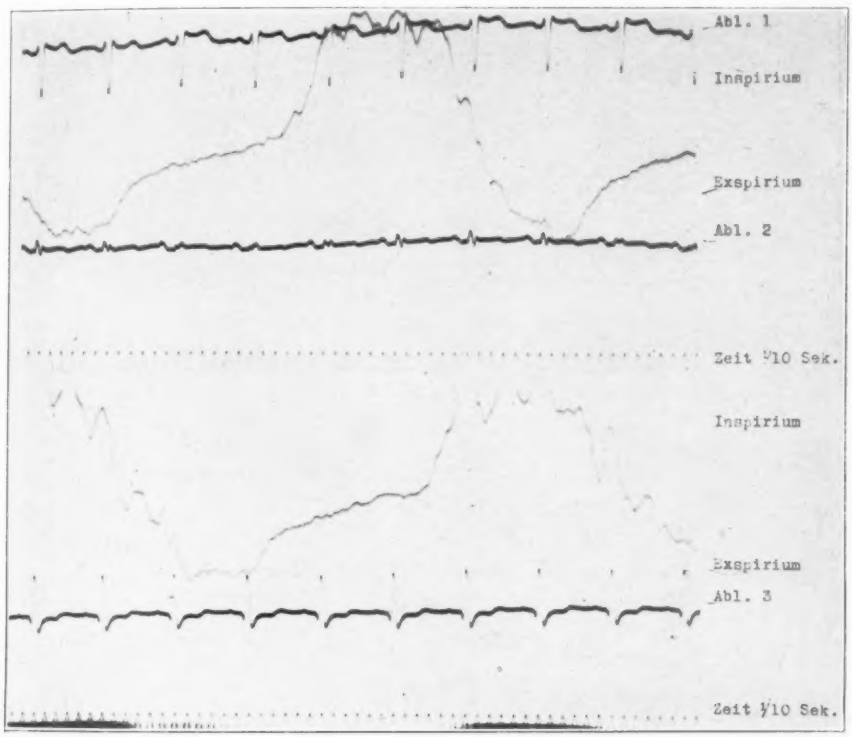

Fig. 1.—Respiratory changes in the form of the QRS wave occurring in Lead II.

grams were made with a Siemens-Halske instrument, using needle electrodes placed in the skin of the chest and left femoral region. The respiratory waves were recorded by the pneumotachograph of Hochrein, the patient reclining and breathing normally. These records are made routinely not only from all patients in the heart wards, but also from those occupying other medical stations.

Seventy-four instances of so-called form changes were found, 44 of simple variations in height with a difference of more than 2 mm., and 4 of a shifting P-wave form. The changes in form consisted of several types. The appearance and disappearance of slurring or notching of

R or S was frequently observed, the deformity coming gradually as the wave decreased in height, during expiration in the case of R_3 and S_1, and during inspiration with R_1 and S_3. Changes in Lead II appeared in most instances during inspiration. Exceptions to this general rule, however, occurred in all leads, most often with R_3. Other changes consisted in the shifting of the position of a slur or notch usually simultaneously with a change in the height of the wave, although instances were found in which a difference in height was not measurable. As may be expected, these changes were found most often in Lead III, in which

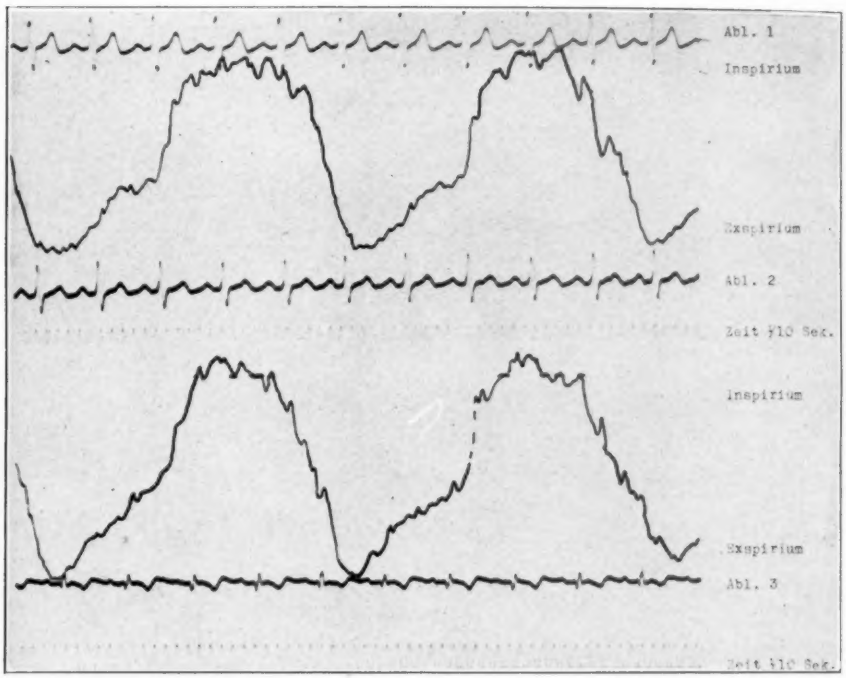

Fig. 2.—Respiratory changes in the form of the QRS wave in Lead III.

there were 48 instances. In Lead II there were 11; in Lead I, 10; in Leads I and III, 3; and in Leads II and III, 1. Changes in the form of P in relation to respiration occurred in only 4 cases. In no instance were extrasystoles found to occur consistently in one phase of respiration.

The accompanying table shows the frequency of respiratory variations in form and height of QRS in the principal types of heart disease. Of 74 patients with form changes 57, or 77 per cent, had definite clinical evidence of heart disease, while of 44 with variations in height only, 26, or 59 per cent, were clinically abnormal. Of the 57 cardiopaths in the first group, 31, or 42 per cent, of the total, were classed under coronary sclerosis, generalized arteriosclerosis or hypertension. Although these

data do not furnish the incidence of notching and slurring irrespective of respiration, it is certain that these form changes occur rather frequently in cases of heart disease especially of the degenerative type due to arteriosclerotic changes.

TABLE I

SHOWING THE INCIDENCE OF RESPIRATORY CHANGES IN QRS IN RELATION TO THE PRINCIPAL TYPES OF HEART DISEASE

DIAGNOSIS	LEAD I	LEAD II	LEAD III	LEADS I, III	LEADS II, III	TOTALS	CHANGES IN HEIGHT ONLY
Coronary sclerosis, hypertension, arteriosclerosis	5	5	19	2		31	14
Rheumatic heart disease	1	2	3	1	1	8	4
Chronic pulmonary disease	1	1	5			7	1
Hyperthyroidism	1	2	2			3	2
Aortic syphilis			2			4	0
Obesity			1			1	1
Paroxysmal tachycardia			2			2	0
Congenital lesions			1			1	1
Miscellaneous							3
Clinically normal hearts	1	2	14			17	18
Totals	9	12	49	3	1	74	44

COMMENT

The explanation of the variations in form of the QRS wave is apparently closely connected with that of variations in height, since in the great majority of instances the two occur simultaneously and with a more or less constant relationship. The older theory of shifting of the electrical axis due to the mechanical effect of diaphragmatic movements has been to a certain extent refuted by various authors. Stimulation of the sympathetic and paralyzing the vagus were demonstrated to produce similar changes by Einthoven, Rothberger and Winterberg.

Condorelli[1] found variations of this phenomenon occurring in the same individual with variations in the functional condition of the myocardium. He also observed that the depth of respiration in certain instances scarcely modified the changes in the height of R. Administration of ¼ mg. of adrenalin intravenously produced in one patient marked respiratory variations. After experimental ligation of a coronary artery in anesthetized animals he observed a striking change in all waves,

which, however, occurred not with the artificial breathing produced by intratracheal insufflation, but with the involuntary, ineffectual respiratory movements of the animal. He therefore concludes that shifting of the cardiac axis has little to do with these changes and that in all probability the extracardiac nerves can cause an increase or decrease in the potential of the heart's action current. Furthermore, in some 20 of the patients here recorded, in whom the movements of the diaphragm were abnormally limited (as observed fluoroscopically), it was observed that marked respiratory variations in form and height occurred.

Evidence against the theory of vagal and sympathetic influence is demonstrated by the failure of atropine or vagal stimulation to decrease or increase the respiratory variations. Moreover, sinus arrhythmia, which is commonly believed to be caused by changes in vagal tonus, is considered rare in cases of definite heart disease, whereas respiratory variations in the form and height of QRS waves appear frequently in these individuals.

Other factors should be considered as having a possible rôle in the production of these phenomena. It has been demonstrated experimentally by Hochrein[5] that the blood flow in the coronary arteries varies regularly and definitely with the respiratory phase, which may be a factor in changing the potential of the action current. Variations in intrathoracic pressure affecting the amount of filling or distention of the left or right ventricle may cause a shift in the electrical axis. Chemical changes in the blood and in the tissue fluids, occurring with respiration and altering the chemical state of the myocardium, may also have an effect.

Since it is certainly far from clear what the important causative factor is in the production of these phenomena, there is need for further investigation of the problem, especially along experimental lines. Respiratory changes in the form of the electrocardiogram, though of very frequent occurrence, have heretofore not received sufficient attention in the study of this subject.

SUMMARY

In 2000 cases respiratory curves and electrocardiograms were recorded simultaneously. Respiratory changes in the form of the QRS wave were found to occur rather frequently in patients with heart disease, especially in those in the arteriosclerotic group. The cause of the respiratory changes does not appear to be due to a shifting of the axis caused by movements of the diaphragm. The influence of the vagus and sympathetic nerves, as well as changes in coronary blood flow, is briefly discussed.

The author wishes to express appreciation to Privatdozent Dr. Max Hochrein for suggesting this study and for his help and advice in the preparation of this paper.

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Department of Clinical Reports

MULTIPLE RUPTURE OF HEART BY INDIRECT TRAUMA, COMPLICATED BY MURAL THROMBOSIS AND EMBOLISM*

OSCAR SWINEFORD, JR., M.D.
UNIVERSITY, VA.

SPONTANEOUS rupture of the heart is relatively rare. Krumbhaar and Crowell,[1] in 1925, made a detailed analysis of 22 of their own cases together with the 632 cases recorded in the literature since 1872. Their conclusions have been confirmed but not significantly amplified by subsequent reports of about 100 additional cases by various authors.

Most spontaneous ruptures occur through recent necrotic infarcts, some through aneurysmal dilatations of healed infarcts, and a few through abscesses, gummata, tubercles, metastatic tumors or parasitic cysts. Rarely the heart shows only the relatively benign changes of brown atrophy, fatty degeneration, and slight coronary sclerosis with atrophy and fibrosis.

The exciting cause is usually as insignificant as walking, eating or defecating. Sometimes emotional crises, violent exertion or, rarely, indirect trauma may bring about the rupture.

Nearly 80 per cent of spontaneous ruptures occur in the left ventricle, 10 per cent in the right ventricle, 6 per cent in the right auricle, and 2 per cent in the left auricle. Rupture of the septum is rare. There are several instances on record of interventricular, but only one[2] of interauricular, rupture. Multiple ruptures are not mentioned by Krumbhaar and Crowell but have been noted several times by others. No record of mural thrombosis at the site of the rupture with secondary pulmonary embolism has been found.

The following case is reported because it represents a unique combination of several rare aspects of spontaneous rupture of the heart: 1. The myocardium was not markedly abnormal. 2. Indirect trauma was the exciting cause. 3. The ruptures were multiple and had perforated: (a) the interauricular septum completely, (b) the interventricular septum partially, and (c) the anterior wall of the right ventricle with the exception of a transparent film of epicardium. 4. A mural thrombus had formed at the site of the interauricular defect and had given rise to a pulmonary embolus.

*From the Department of Pathology, University of Virginia Medical School, University, Virginia.

Spontaneous rupture of the heart is usually found about once in 1500 autopsies. This is the fourth case in the 1500 autopsies of the University of Virginia Hospital. Two of the others have been reported previously.[2, 3]

CASE REPORT

E. P., a colored woman about seventy-five years old, was admitted on the Orthopedic Service about twenty minutes after being struck from behind by an automobile. Her health had been excellent before the accident. For convenient reference the clinical course is presented in the form of a protocol.

PROTOCOL OF CLINICAL COURSE*

TIME	CLINICAL OBSERVATIONS	TREATMENT
10:00 A.M.	Hit by automobile.	
10:20 A.M.	Admitted to hospital. Examination disclosed: multiple fractures of ribs and legs, abrasions of left forehead, moderate degree of shock, pulse 100 and regular but for occasional extrasystoles. No dyspnea nor orthopnea. This was followed by a short period of improvement.	1000 c.c. normal saline I. V. Morphine gr. ¼. Hot water bottles.
12:20 P.M.	Pain in chest with increasing orthopnea and restlessness.	Morphine gr. ⅙.
12:25 P.M.	Gasping for breath, respirations 8, pulse 110 and regular, blood pressure 70/20, pupils constricted.	Adrenalin M. XV Caffein sodio-benzoate gr. 7½.
2:00 P.M.	Better. Respirations 16, blood pressure 110/40.	
3:00 P.M.	Semicomatose, slight pulmonary edema.	
3:30 P.M.	Better. Respirations and pulse satisfactory.	Fractures reduced and splints applied.
3:35 P.M.	Respiration and heart beat ceased suddenly, without a sigh or gasp, just after splints were applied.	

*At no time were heart murmurs heard nor were irregularities of the pulse detected (except occasional extrasystoles). Electrocardiograms were not made.

Autopsy Findings.—The body was that of an aged colored woman. External examination showed two small bruised areas on the left forehead, multiple depressed fractures of the right ribs, and compound comminuted fractures of both tibiae and fibulae.

Internal examination disclosed fractures of the fourth, fifth, sixth, and seventh right ribs near their vertebral ends. The posterior fragments were depressed and had perforated the parietal pleura giving rise to a large hematoma. These and the

fourth, fifth, and sixth left ribs were also fractured in the parasternal region but the fragments were not displaced. There was no fracture of the skull.

Brain: There were many small subarachnoid hemorrhages over the right frontal and parietal and the left parietal surfaces of the cerebrum. The fluid in the lateral ventricles was blood tinged. The vessels beneath the lining of the ventricles were congested. The choroid plexus was normal.

Lungs: There were massive adhesions between the visceral and parietal layers of the right pleura with an extensive extrapulmonary hematoma in the region corresponding to the depressed right rib fragments. An embolus occluded the middle branch of the right pulmonary artery. This lung was markedly edematous and

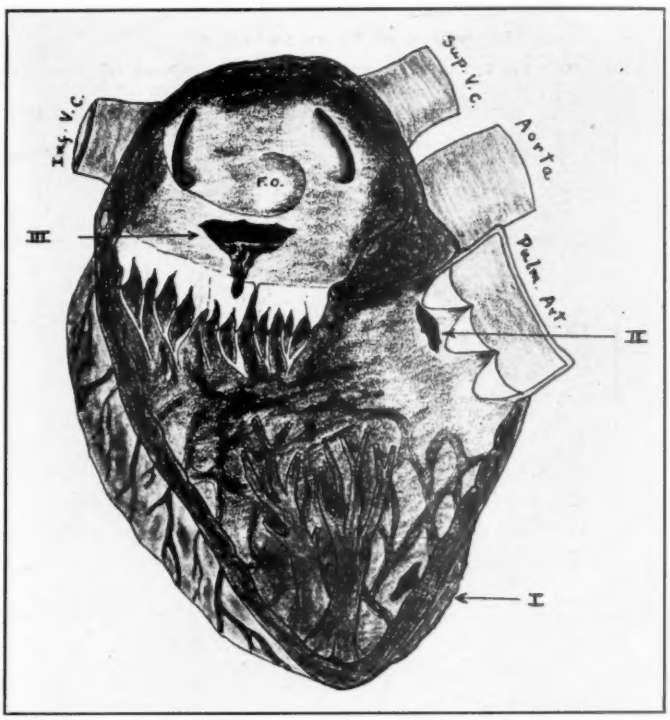

Fig. 1.—Diagrammatic sketch of right auricle and ventricle. *I*, Rupture of wall of right ventricle with subepicardial hematoma and narrow opening into ventricle. *II*, Partial rupture of interventricular septum beneath the posterior and medial cusps of the pulmonary valve. *III*, Rupture of the interauricular septum with Y-shaped thrombus attached along lower border.

slightly atelectatic. The left lung was also atelectatic and had a few pleural adhesions but was otherwise normal.

Heart: Weight 308 grams. Over the lower anterior surface above and to the right of the apex was an area of subepicardial hemorrhage, 6 by 3 cm., which communicated with a small ragged perforation of the wall of the right ventricle 3 cm. above the apex and adjacent to the septum. The ventricular aspect of this perforation was about 1 cm. in diameter. (Fig. 1, *I*.) The subepicardial opening was just large enough to admit a 1 mm. probe readily. The subepicardial hematoma contained about 2 c.c. of blood and was separated from the pericardial cavity by a transparent film of epicardium. The pericardium contained a few cubic centimeters of pale clear fluid.

Just beneath the medial and posterior cusps of the pulmonary valve (Fig. 1, *II*) was a small partial rupture through the endocardium and about half of the myocardium of the interventricular septum.

There was a perforation of the interauricular septum, 2.5 cm. in diameter, between the fossa ovale and the A-V valves (Fig. 1, *III*). The edges of this perforation were smoother on the left than on the right. There was diffuse petechial extravasation of blood in the septum with corresponding subepicardial hemorrhages in the region of the right A-V junction. In the right auricle attached along the inferior border of the perforation, extending down almost to the tricuspid valve, was a Y-shaped thrombus (Fig. 1, *III*) which appeared to be the source of the embolus found in the middle branch of the right pulmonary artery.

The myocardium appeared normal grossly except at the sites of the ruptures. There was no evidence of infarction. The coronary arteries were slightly atheromatous but were not obstructed by thrombi, emboli, or calcium plaques. The aortic valve cusps were slightly calcified at the commissures. There was slight arteriosclerosis of the aortic arch.

Microscopic examination of the heart showed brown atrophy, fatty degeneration, small areas of atrophy and fibrosis, subepicardial and interauricular interstitial hemorrhages, and moderate intimal degeneration of the smaller coronary branches. There was no evidence of infarction.

The liver, spleen, kidneys, pancreas, adrenals, uterus, tubes, and ovaries were not significantly abnormal.

DISCUSSION

The details of the mechanism causing the heart to rupture are, of course, not known, but they furnish material for interesting, though unprofitable, speculation. There is little doubt, however, that the severe, sudden, crushing blow from behind was the exciting cause and that the myocardial degeneration, though very slight for a person seventy-five years of age, was the predisposing cause.

Death was probably due to the pulmonary embolus, with shock, contusion of the brain, and acute and chronic myocardial damage as important contributing causes. In view of the location of the ruptures the absence of murmurs is not surprising. However, the absence of disturbances of conduction is extraordinary in view of the fact that all three of the ruptures were close to the bundle of His.

SUMMARY

A unique case of rupture of the heart by indirect trauma is presented. The interesting features are:

1. Indirect trauma is a rare exciting cause.
2. The ruptures were multiple, which is rare. One was of the interventricular septum, which is also rare. One was of the anterior wall of the right ventricle, which is not uncommon. The third was of the interauricular septum. This has been reported once before.
3. A fresh thrombus formed along the edge of the interauricular rupture and gave rise to a pulmonary embolus. This has not been reported before.

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RUPTURE OF SPLENIC INFARCT IN SUBACUTE BACTERIAL ENDOCARDITIS*

ARTHUR C. KERKHOF, M.D., AND ELLIS K. GIERE, M.D.
MINNEAPOLIS, MINN.

IN 1923 Blumer[1] published his monograph on subacute bacterial endocarditis. He reports that 115 infarcted spleens with 16 septic infarcts were found in 150 autopsies. He does not mention a single case of rupture of a splenic infarct. On searching the literature, we find reports of only three cases of rupture of infarcted spleen into the peritoneum. Todd[2] in 1919 reported a case of rupture of a septic splenic infarct. The infarct in this case was caused by a septic embolus from a gunshot wound of the leg with an infected compound fracture, and death was due to hemorrhage into the peritoneal cavity. Krokiewicz[3] in 1926 reported the only case of rupture of the spleen in subacute bacterial endocarditis. He also stated that up to that time his case was unique in the literature. In this case of subacute bacterial endocarditis death was due to rupture of the splenic infarct and hemorrhage into the peritoneal cavity. Autopsy showed vegetations on the aortic valve, a septic infarct in the spleen which had ruptured into the peritoneal cavity, filling it with blood. F. J. Billings[4] in 1928 reported a splenic abscess of unknown origin which ruptured into the peritoneal cavity, causing a generalized peritonitis and ileus. It is because of the extreme rarity of the condition and rather misleading clinical findings that we are reporting the following case.

CASE REPORT

O. L., aged seventeen years, was admitted to Minneapolis General Hospital April 11, 1931. Patient had rheumatic fever six years previously, inflammatory and migratory in type, causing him to be in bed three months. He had had similar attacks occasionally for short periods of time since. Dates and periods of these attacks were not known. There was no history of shortness of breath; but he had noticed slight weakness on extreme exertion.

During the fall of 1930, the patient had not been well, had been losing weight (18 pounds in six months), had noticed that he perspired frequently, but had been able to keep up his school work. In January, 1931, the patient ceased going to school because of his weakened condition. He continued to lose weight, noticed frequent colds, and never felt warm, although he had no definite chills. He had aches and pains in his muscles, especially in his legs.

Ten days previous to admission to the hospital patient noticed vague gastric distress, no definite pain, no nausea or vomiting, no food disturbance. Bowels functioned entirely normally. One week before admission patient developed a pain in left upper quadrant under left costal margin. At first he was not very clear as to the nature of this pain but stated later that the pain was sudden and severe in on-

*From the Department of Medicine, University of Minnesota at the Minneapolis General Hospital.

set. The pain was intensified by deep inspiration. Duration of pain one day. Patient felt fairly well after pain left.

Three days before admission to the hospital he developed a sudden severe pain located at the left costal margin, lasting about five minutes. The pain gradually became diffuse over the entire abdomen. The pain was steady, not crampy or colicky in type. At the onset of pain he had a small bowel movement, normal in color and containing no pus or blood. The same day he noticed that his abdomen was becoming distended and tense. Patient stated that he vomited four times during the forty-eight hours preceding admission to the hospital. The vomitus was brown in color and tasted foul. Patient thought that he had been passing urine more frequently the preceding few days and that it was darker in color than usual.

Physical Examination: White male, aged seventeen years, apparently anemic, fairly cooperative, in considerable pain. Head, pupils react to light, teeth carious, moderate postnasal discharge. Marked pulsation of vessels of the neck. Thyroid small. Chest, lung fields negative to percussion and auscultation. Heart boot-shaped, to percussion, markedly enlarged to left, no enlargement to the right. Retraction of interspaces with pulsation of the heart. Systolic thrill at base of the heart. No thrill felt at the apex. Systolic and diastolic murmur heard over the aortic area and well transmitted down the left border of the sternum. There was a fairly loud systolic murmur at apex of heart with faint diastolic murmur. It was felt that the diastolic murmur at the apex was a transmission from the aorta. The blood pressure was 148/48 mm. Abdomen distended, belly wall tense, no visible peristalsis, no borborygmi; tympanitic to percussion. Liver and spleen not enlarged to percussion. Spleen not palpable. Distension of abdomen interfered with this examination. There was diffuse tenderness over the entire abdomen to pressure with slight rebound tenderness localized in the right lower quadrant. There was a suggestion of a mass in the left lower quadrant. Rectal examination revealed sense of fullness in midline of pelvis with definite suggestion of a mass. Moderate tenderness to the examining finger. Extremities negative, no edema.

Impression on admission:
1. Aortic stenosis and insufficiency.
2. Mitral insufficiency.
3. Subacute bacterial endocarditis.
4. Partial intestinal obstruction,
   a. mesenteric thrombosis or embolus,
   b. appendicitis with ileus.

Laboratory Findings: Urine, sp. gr. 1021, no albumin, 15-20 R.B.C. and 3-4 W.B.C. per field. Leucocytosis of 27,200, differential P.M.N.'s 86 lymph. 13, mono. 1. Leucocyte count twelve hours later 20,950.

Six-foot heart plate: Total transverse diameter of chest 27.4, Ml. 12.1, Mr. 2.4. Total of heart 14.5 cm. Left ventricular type of enlargement. Diaphragm on left was poorly defined. Moderate effusion seen occupying the left pleural cavity. Lung fields clear.

Plates of the abdomen demonstrated a moderate accumulation of gas in both the large and the small bowel, the appearance suggesting an intestinal stasis, paralytic rather than on a mechanical obstructive basis. There was a suggestion of an increased density occupying the medial portion of the right iliac fossa suggesting a probable mass in this region, although this was not entirely definite.

Course: Patient was afebrile on admission. Surgical consultation was held, but it was deemed inadvisable to do a laparotomy due to the critical condition of the patient and to the fact that following rectal examination the patient passed a large amount of flatus with a watery brown stool. It was considered that the obstruction which seemed paramount on admission had been relieved by nonsurgical pro-

cedures. Temperature remained normal until one hour before death, then rapidly rose to 106° (rectal). Patient was in hospital thirty hours before death.

The autopsy was performed by Dr. N. H. Lufkin, pathologist at the Minneapolis General Hospital, one and one-half hours after death. On opening the abdomen, the peritoneal cavity was found to contain about 2000 c.c. of fibrinopurulent fluid. The omentum was matted over the bowels which were distended with gas and fluid. Peritoneal surfaces were all greatly roughened and reddened, and efforts to release the fibrinous adhesions between the bowel loops caused rupture in a number of places. The appendix was found to be normal.

The pleural cavities were free. The pericardial sac was slightly adherent to the left lung and was firmly adherent to the chest wall in the left midclavicular line and also to the right lung. The pericardial cavity was completely obliterated by old fibrous adhesions between the sac and epicardium. There was a slight bronchopneumonia in both lungs.

Heart weighed 510 grams. There was a great hypertrophy of the left ventricle with slight dilatation of this chamber. Pulmonary and tricuspid valves were normal. The aortic valve was greatly thickened and stiffened by scar tissue and calcium infiltration. The leaflets were adherent to one another at their commissures where there were great retraction and thickening. The margins were rounded and thickened by fibrous tissue, while at the bases of each there were large calcified masses, especially on the aortic surfaces. The lesion was of such an extent as to produce a severe grade of stenosis with some degree of regurgitation. The mitral valve was likewise thickened and stiffened, especially at the margins, with thickening of the chorda tendineae. There was a scarring between the two leaflets. On the margin of the mitral leaflets were found a number of small soft vegetations, some of which were rounded and pedunculated. A smear of one of these small thrombi showed the presence of numerous streptococci. The coronary arteries were normal. The myocardium was normal.

The spleen weighed 220 gm. It was firmly adherent to the diaphragm by fibrous adhesions so that considerable tearing resulted from efforts to remove it. The substance of the spleen was quite firm, but at its periphery were a number of irregular white infarcts extending to the hilus. The largest of these lesions was 3 to 4 cm. at the periphery and had undergone extensive purulent softening. Capsule over this area was extremely thin and was broken at the time of removal. Smears from its purulent content were loaded with short chained streptococci. There was a pale infarct 2 cm. in diameter in the upper pole of the left kidney.

The postmortem diagnoses were:

Old rheumatic endocarditis of mitral and aortic valves.
Recent bacterial endocarditis.
Septic infarction of spleen with rupture and streptococcus peritonitis.
Old healed pericarditis.

In summing up this case, the whole picture unfolds itself. The patient developed a rheumatic endocarditis which resulted in aortic insufficiency and stenosis and some mitral damage six years before. Then sometime during the fall and winter of 1930-1931 he developed a bacterial endocarditis. One week before admission he developed an infarct or multiple infarcts of the spleen. This caused the sudden severe pain in the left upper quadrant which was increased by deep respiration because of subdiaphragmatic inflammation. This pain then subsided and the patient felt better. Three days before admission the infarct, which

had now become an abscess, ruptured into the general peritoneal cavity, leading to a purulent peritonitis with paralytic ileus which obscured the picture and which eventually caused death. In retrospect we feel that with the story as we have it now, which we did not have on admission, we might at least have included the correct diagnosis in our diagnostic probabilities. We do not believe that surgical intervention would have offered any other end-result, first because of the severity of the peritonitis, and second because of the underlying process, namely subacute bacterial endocarditis.

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William Sydney Thayer

JUNE 23, 1864-DECEMBER 10, 1932

IT is difficult to speak of the loss sustained by American medicine in the death of Doctor Thayer without seeming to resort to extravagance and hyperbole.

The measure of his beneficent influence upon his profession is not to be reckoned merely as the sum of his accomplishments as an investigator, a teacher, a scholar, and a clinician, great as these undoubtedly were. Of greater significance perhaps than all of these sterling accomplishments was the influence of his personality upon his colleagues and upon the generations of students fortunate enough to come under his influence.

Even more than his remarkable professional attainments it was his character, his ethical standards, his generous, disinterested attitude toward every question, his eagerness to help, his capacity for warm friendship that won for him the unique position he occupied.

The loss suffered by the profession at large is fully shared by THE AMERICAN HEART JOURNAL and its editorial staff, of which he was an honored and beloved member.

Department of Reviews and Abstracts

Selected Abstracts

King, John T., and McEachern, Donald: The Nature of the Physical Signs of Bundle-Branch Block. Am. J. M. Sc. **183**: 445, 1932.

An analysis of 50 consecutive cases of bundle-branch block showed the following physical signs: visible reduplication of the apex thrust in 42, palpable reduplication in 40; the first heart sound was split into two elements in 28, there were two separate systolic murmurs in 6 and a single first sound with a separate murmur in 8. On the basis of these signs a correct diagnosis was made prior to knowledge of the electrocardiogram in 34 of 40 attempts; the presence of bundle-branch block was suspected in 2 but was not definitely diagnosed; the diagnosis was not made in 4. There was a difference of opinion in 4 other cases. In the remaining 6 cases the presence of bundle-branch block was recognized only by electrocardiograms.

In 3 patients showing complete auriculoventricular block as well as intraventricular block, the diagnosis of both conditions was made in 2 cases from clinical signs and the signs were equally clear in the third case; signs of bundle-branch block were found, and the condition was recognized clinically in 5 or 7 patients showing both fibrillation and bundle-branch block. The latter two groups of cases show that the auricles are not concerned with the physical signs of bundle-branch block.

Presystolic gallop bears a superficial resemblance to the signs of bundle-branch block; however, clinical evidence and apex cardiograms show the two conditions to be different; presystolic gallop being truly presystolic, the signs of bundle-branch block being limited to systole and causing a division of the apex systolic plateau. Normal controls failed to show systolic reduplication.

A cinematographic film of the movement of a straw attached to the cardiac apex showed a double systolic thrust in each of 5 consecutive cases of bundle-branch block.

Mufson, Isidor: A Study of the Capillary Pressure in Nephritis and Hypertension. Am. J. M. Sc. **183**: 632, 1932.

This investigation represents a further attempt to correlate variations of blood pressure within the minute vessels with the clinical findings in acute and chronic nephritis and in essential hypertension. Special attention has been given to the influence of capillary pressure on the development of edema. The comparison has been made between the capillary morphology found in essential hypertension and peripheral arteriolar spastic (Raynaud's) disease. From their marked difference it seems more probable that essential hypertension is due not solely to arteriolar spasm but to a generalized arterial spasm.

The frequent association of high capillary blood pressure with renal disease is indicative of a spasm response due to a severe involvement of the systemic capillary system. A relationship between the capillary pressure and the osmotic

pressure of the blood to the presence of edema has been found to exist in nephritis.

Bellet, Samuel, and Gouley, B. A.: Congenital Heart Disease With Multiple Cardiac Anomalies. Am. J. M. Sc. 183: 458, 1932.

Congenital heart disease in an infant is reported which presents the following unusual and rare anomalies: atresia of the aorta, hypoplasia of the left ventricle with marked thickening of its wall, hypertrophy, premature closure of foramen ovale, dilatation of right auricle and ventricle, diminutive left auricle and fibrosis of the myocardium of the left ventricle. In addition another very rare anomaly was found, the remains of the sinusoids of the embryonic heart. The incidence, theories of the origin of these anomalies and the resulting disturbances of the fetal circulation are discussed.

Samuels, Saul S.: The Incidence of Thrombo-Angiitis Obliterans in Brothers. Am. J. M. Sc. 183: 465, 1932.

In the examination of over 500 cases of thrombo-angiitis obliterans, the author has observed three families in which it occurred in brothers. In the first family, 3 brothers, aged thirty-four, thirty-three and twenty-nine years, showed signs of the disease. Parents of these young men were born in Austria and were apparently free from any evidence of peripheral arterial disease. Another family in which three brothers, aged forty-two, thirty-five and forty years, were affected with thrombo-angiitis obliterans was of Russian Jewish nationality; all of these were born in Russia. The third family consisted of 2 members of Austrian descent aged forty-eight and forty-three years and were born in America.

The author points out certain peculiarities of the disease, notably, its predominance in Jews, its predilection for young males, its association with cigarette smokers, its occasional occurrence in brothers with no direct evidence of inheritance.

Parkinson, John: Coronary Thrombosis. Brit. M. J. No. 3741, 549, 1932.

The author summarizes this presentation before the Section of Medicine at the Centenary meeting of the British Medical Association as follows: Angina pectoris is a serious disease of the heart which is manifested by pain across the chest or at the sternum, often extending into the arms, and which is due to deficient coronary circulation or imperfect blood supply. There are two main varieties, but their specific pain differs only in intensity, and their pathology has a common factor in myocardial ischemia. When the pain is brief and depends on exertion, anginal pain is known as angina of effort, and arises from ischemia due to localized arterial spasm. When an attack of anginal pain is unrelated to exertion and sufficiently prolonged, and complicated by the symptoms of infarction, it is known as coronary thrombosis, and arises from the resulting necrotic ischemia. Between these two varieties all grades of angina pectoris are encountered, in the main depending on the severity and extent of the coronary disease and the effect on the myocardium, whether the ischemia is transient (arterial spasm) or permanent (infarction). Cases of angina pectoris range from simple to severe, and present a similar pain (anginal) of varying intensity and reveal at their source a vascular identity.

Angina of effort may be initiated, complicated or terminated by coronary thrombosis. By this a simple angina (of effort) can be converted into a sort of compound or complicated angina (with shock, etc.). The correlation between anginal pain and vascular lesion is not exact, for the worst cases of angina of effort approximate to coronary thrombosis. Angina of effort is fairly inclusive of all cases of angina

pectoris excluding coronary thrombosis, cases with spontaneous attacks of pain at rest being almost invariably subject to angina on exertion.

Too much stress has been laid upon the gravity of angina pectoris. It is inseparable from a risk of sudden death, but this may be deferred for years. In attacks of coronary thrombosis and in the severer grades of angina of effort the pain is extreme and the danger is great, but milder forms are common and often run a tolerable course. There is every gradation between mild angina of effort and severe coronary thrombosis as there is every grade of coronary disease. Too much attention has been centered on the anginal death and too little on the anginal life and its management.

Bartels, Elmer C., and Smith, Harry L.: Gross Cardiac Hypertrophy in Myocardial Infarction. Am. J. M. Sc. **184:** 452, 1932.

A study has been made of the weights of the heart in forty-two cases of cardiac infarction in which all other known or supposed causes of cardiac hypertrophy had been excluded. Of the forty-two cases, in 37 (88 per cent) there was definite gross cardiac hypertrophy. In five cases the weights of the hearts were not above normal. The minimal increase in weight was 18 grams (9 per cent), the maximal increase 342 grams (108 per cent), and the average increase 132 grams (42 per cent). From the data given, it would appear that cardiac infarction is a definite cause of cardiac hypertrophy.

Glover, J. Alison, and Wilson, Joyce: The End-Results of the Tonsil and Adenoid Operation in Childhood and Adolescence. Brit. M. J. No. 3740, 506, 1932.

The following summary of this paper which was read in opening a discussion of this subject, in the Section of Otolaryngology at the Centenary meeting of the British Medical Association in London, presents very important findings and conclusions from a very extensive study.

The rising flood of tonsillectomy has been shown in the immense and rapid increase in the numbers of operations annually performed and by the astonishing fact that more than half the most carefully nurtured children in this country are now subjected to it, whereas forty years ago none of their parents underwent the operation. While the incidence of tonsillitis is at least as high among the poor as among the well-to-do, the children of the latter have an incidence of tonsillectomy at least four times as high.

A review of the literature suggests that, with the single exception of diphtheria, the incidence of the ordinary infectious diseases is unaffected by tonsillectomy; that while the incidence of recurrent sore throats is perhaps somewhat diminished, that of frequent colds is unaltered, or perhaps slightly increased. The incidence of otitis and mastoid disease is the same, or perhaps slightly increased upon the tonsillectomized, while their liability to bronchitis and pneumonia is also probably slightly increased.

The evidence with regard to the prophylactic and therapeutic end-results of tonsillectomy on acute rheumatism, chorea and carditis is distressingly confusing. There is not sufficient cause for the routine removal of apparently healthy tonsils in a rheumatic or potentially rheumatic child, simply as a measure of prophylaxis against acute rheumatism. Removal should only be undertaken if there is some definite indication.

Observations have been detailed on the relative incidence of nasopharyngeal infections upon the tonsillectomized and the nontonsillectomized pupils of a school population numbering nearly 14,000. Most of these pupils were between the ages of thirteen and one-half and eighteen years and belonged to the well-to-do classes. Save for two, with a total of 1,100 pupils, all the schools were boarding schools. Rather more than half of this population was tonsillectomized. Some of the observa-

tions cover a period of seven terms, or two and one-third years, while others are confined to certain terms of epidemic prevalence.

These interim observations (so far as they have gone) give no statistical support to the theory that the removal of tonsils closes an entrance for infectious or respiratory diseases. Hardly any cases of diphtheria have occurred, so that the prophylactic value of the operation in this disease could not be assessed. In scarlet fever, otitis media and mastoid disease no significant differences were observed. In the two latter diseases the slight differences observed were in favor of the non-tonsillectomized.

These observations, based on actual attack rates in a school population, generally support the conclusions arrived at by Cunningham from a study of the histories of a similar number of somewhat older students. She found that the tonsillectomized pupils have a history of higher incidence of all illnesses and suggests that the fact that children who are often ill are those most frequently tonsillectomized may be the explanation. Comparing the proportion of the amount of illness reported before and after tonsillectomy in the same pupils, she suggests that the removal of tonsils had little influence in lessening the susceptibility to most infections.

The authors profess to hold no brief for the retention of diseased or really obstructive tonsils or adenoids, nor do they wish to cast doubt upon the high value of the operation in cases in which there is sure evidence of toxic or obstructive damage. A review of the literature and the epidemiological observations made on a highly tonsillectomized child population suggest, however, that the excellent end-results of tonsillectomy in selected cases have been statistically overweighted by indifferent end-results in cases in which the operation has been performed without sufficient indications as a more or less routine prophylactic ritual. In their opinion, a large proportion of the tonsillectomies now done in children are unnecessary, entail some risk and give little or no return.

Smith, Harry L., and Willius, Fredrick A.: Pericarditis. I. Chronic Adherent Pericarditis. Arch. Int. Med. **50:** 171, 1932.

The records of necropsies were clinically studied, and among the 8,912 cases, 373 cases of pericarditis were found, an incidence of 4.2 per cent. One hundred and forty-four cases of adherent pericarditis were studied with particular reference to clinical and pathological correlation.

A marked predominance of the incidence in males occurred. Etiological diseases occurred in the following order: (1) rheumatic fever, (2) intrathoracic infection, (3) cardiac infarction, (4) syphilis (certainly present, probably etiologic), (5) neoplastic invasion. The weights of the hearts were determined in 105 cases. The pericardium was partially calcified in 15 cases (10.4 per cent). Associated cardiac diseases occurred in 77 cases. These in order of frequency were: (1) coronary sclerosis, (2) rheumatic heart disease with mitral stenosis, (3) hypertensive heart disease, (4) rheumatic heart disease with aortic insufficiency, and (5) aortic syphilis.

The predominant clinical syndrome was referable to the heart in 57 cases and was in no manner related to the heart in 87 cases. The latter comprised a miscellaneous group of diseases. Death from heart disease occurred in 39.5 per cent of the cases; whereas the heart was not directly concerned with death in 60.5 per cent.

Smith, Harry L., and Willius, Fredrick A.: Pericarditis. II. Calcification of Pericardium. Arch. Int. Med. **50:** 184, 1932.

Sixteen proved cases of calcification of the pericardium are considered: in fifteen of these cases the diagnosis was established at necropsy and in one case in life. All of the sixteen patients had extensive chronic adhesive pericarditis. The diagnosis

made in life was accomplished by roentgenologic examinations. Four other clinical cases are described, but the findings were not sufficiently striking for them to be classified as proved cases. The single etiological factor that affected the largest number of cases was rheumatic infection. Tuberculosis was not present in any one of the proved cases. It was present in one of the four unproved cases. It would appear that calcification of the pericardium is a sequel of extensive chronic adhesive pericarditis and is an end-result of the same inflammatory process that produces chronic adhesive pericarditis. It is not a common condition, for it was found in only 15 of 144 cases of chronic adherent pericarditis found in this series. Recognition of deposits of calcium in the pericardium by means of roentgen rays may be an aid in making diagnosis of chronic adhesive pericarditis, which condition is extremely difficult to recognize.

Smith, Harry L., and Willius, Fredrick A.: Pericarditis. III. Pericarditis With Effusion. Arch. Int. Med. **50**: 192, 1932.

One hundred and thirteen cases of pericarditis with effusion in which necropsy was performed at the Mayo Clinic were studied with special reference to correlation of clinical and pathological data. The cases were grouped according to the character of the effusion as follows: (1) acute purulent pericarditis, (2) fibrinous pericarditis with effusion, (3) tuberculous pericarditis and (4) noninflammatory effusion. A distinct predominance in males occurred. Infections were the etiological factors in eleven cases. Intrathoracic infectious disease occurred with greatest frequency. Infectious processes elsewhere in the body occurred in 31 cases. Only two cases were found in which infection was absent; both of these cases were examples of primary cardiac disease with congestive failure. From this study, therefore, it appears to be established that the presence of infectious intrathoracic disease offers a great chance of the pericardium being involved, and when infectious processes of the body as a whole are considered, the chance of pericarditis is still greater. Thus, the presence of infections should always focus attention on the pericardium and the result may be that purulent pericarditis or fibrinous pericarditis with effusion will be recognized more commonly. It is also of interest to observe the high incidence of pleural effusion occurring with these forms of pericarditis. Fluid was present in one or both pleural cavities in 83 cases. This observation may be applied as an accessory diagnostic sign that favors probability of the presence of pericarditis.

The cardiac weights in sixty cases in which these data were available are presented. Associated disease of the heart occurred relatively infrequently in these cases of pericarditis with effusion. There were 33 cases (29.2 per cent) in which there was associated cardiac disease, which may be compared with 53.5 per cent of cases of adherent pericarditis in which there was such associated disease. The value of so-called characteristic signs of pericardial effusion is considerable, and the presence of any such sign should be properly evaluated but their absence does not justify failure of recognition of pericarditis with effusion. Complaints predominantly referable to the cardiovascular system occurred in only 13.2 per cent of the cases. The clinical syndrome in the majority of the cases was that of sepsis. Death resulting directly and solely from heart disease occurred in only 8.8 per cent of the cases; from sepsis in 77.9 per cent, and from other causes in 13.3 per cent.

Smith, Harry L., and Willius, Fredrick A.: Pericarditis. IV. Fibrinous Pericarditis and "Soldier's Patches." Arch. Int. Med. **50**: 410, 1932.

Sixty-two cases of fibrinous pericarditis without effusion formed a basis of this study. There are also comments on fifteen cases in which there was so-called soldier's patches or milk spots. The incidence in males was greater than that in females. Associated cardiac disease occurred in 31 cases. Although half of the

patients had associated cardiac disease, only 20 had complaints fundamentally related to the cardiovascular system. In the majority of cases in which infection occurred either spontaneously or following surgical intervention, disorders unrelated to the heart were present. The predominant clinical features in 32.2 per cent of the cases were referable to the heart; the remaining cases represented a miscellaneous group of diseases. Death from cardiac disease occurred in 32.3 per cent of the cases. In the remaining cases death was from causes unrelated to the heart. The weights of the hearts in 47 cases were available for study and are discussed.

The major subject of consideration in the etiology of fibrinous pericarditis, as one would anticipate, is an infectious process. Fibrinous pericarditis appears to be one of the simplest and most innocuous forms of pericarditis. It seems to be prodromal to more serious forms of pericarditis, namely, pericarditis with effusions in some cases, purulent pericarditis in others, and adherent pericarditis in many cases in which the patient survives the etiological disease.

Smith, Harry L., and Willius, Fredrick A.: Pericarditis. V. Terminal Pericarditis. Arch. Int. Med. **50**: 415, 1932.

A condition classified as terminal pericarditis occurred in 40 of 373 cases of pericarditis, an incidence of 10.7 per cent. A marked predominance of the incidence in males occurred. Among the major clinical diagnoses in the cases comprising the group, those of carcinoma and nephritis predominated. Associated cardiac disease occurred in 21 cases. Death from heart disease occurred in 10 per cent of the cases. In the remaining cases, 90 per cent of the patients died of causes unrelated to the heart. Pleural fluid was present in 35.4 per cent of the cases, an accessory diagnostic sign suggesting the possibility of pericardial involvement.

Zeek, Pearl: Studies in Atherosclerosis. I. Conditions in Childhood Which Predispose to the Early Development of Arteriosclerosis. Am. J. M. Sc. **184**: 450, 1932.

From January 1, 1931, to January 1, 1932, there were 3,072 autopsies performed on patients dying in the Cincinnati General Hospital. Of this number 1,070 were under thirty years of age; these form the basis for this investigation. The material available for the study consisted of microscopic sections averaging between 15 and 20 slides in each case and including sections from all the principal viscera; additional gross Zenker material and in many cases entire organs preserved in formalin or Kaiserling solution; clinical and pathological reports, the latter including both gross and microscopical findings. A review of this pathological material revealed definite atherosclerosis of the aorta, arteries or arterioles in 79 cases. There may have been other cases since in some of them no formalin material was available for fat stains.

It was found that rheumatic heart disease in this group was almost invariably accompanied by atheromatous changes in the aorta, pulmonary or coronary arteries. All of the four diabetic cases presented atherosclerosis of the aorta. Chronic renal lesions were found in thirty-four of the fifty-two nondiabetic, nonrheumatic cases which presented atherosclerosis and were present also in ten of the twenty-three rheumatic cases. The renal arterioles were the vessels most frequently involved in these cases. The only other pathological lesions which occurred with notable frequency in the atherosclerotic group were: focal lesions in the suprarenal medullae and hypoplasia of the malpighian corpuscles in the spleen.

Zeek, Pearl: Studies in Atherosclerosis. II. Atheroma and Its Sequelae in Rheumatic Heart Disease. Am. J. M. Sc. **184**: 356, 1932.

Sixty-two cases of rheumatic heart disease have been analyzed with reference to the incidence of atheroma, particularly in the aorta, coronary and pulmonary ar-

teries. In twenty-eight patients under thirty-one years of age, the degree of atheroma has been compared with the duration and extent of the cardiac lesions.

Rheumatic heart disease has not been found to predispose to the early development of atheromatous lesions in the aorta, pulmonary and coronary arteries and also in the valvular and left atrial endocardium. Lipoid deposits also have been found in some cases, in the inflamed serous membranes and in certain renal tubules. Lipoid deposition has seemed to begin soon after the onset of cardiac disease and in a very general way has paralleled in degree the cardiac lesions. The atheromatous changes in many cases have been progressive, leading to calcification and when in the valvular endocardium, accentuated stenosis.

Sprague, Howard B., Burch, Hobart A., and White, Paul D.: Adherent Pericardium and Pick's Syndrome. An Autopsy Study. New England J. M. 207: 483, 1932.

A study of 1900 autopsy cases at the Massachusetts General Hospital from 1921 to 1931 in relation to pericardial adhesion is presented with special reference to Pick's disease. This was undertaken for an analysis of the possible opportunities for surgical relief of the condition as related to various etiological factors. A survey of the autopsy material at this hospital from 1893 to 1931 in regard to the incidence of Pick's disease revealed only three cases discovered at autopsy during this period. A comparison of these figures with the discharge diagnoses of the hospital cases over a period from 1923 through 1930 showed, however, that the diagnosis of chronic mediastinopericarditis had been made clinically five times. Further analysis of this clinical group showed no case proved at autopsy, but did reveal two living, in which the diagnosis appeared to be correct.

In the thirty-five-year period, during which time 6100 autopsies were studied, only six cases of adherent pericardium with a rheumatic history came to autopsy in which valvular disease was not present. None of these cases had Pick's disease.

Tuberculosis of an insidious type is the most probable cause of the constricting pericarditis of Pick. In the presence of rheumatic valvular disease and the inevitable myocardial involvement of these cases, pericardial adhesions appeared to play a secondary part in the picture of congestive failure, and in no case could it be held to be true constricting pericarditis. Adhesive pericarditis in middle or old age, even when calcified, in the absence of valvular disease is an unimportant cause of symptoms and is very rarely a contributory cause of death.

It appears unjustifiable to recommend pericardial resection following acute rheumatic pericarditis to prevent the later effects of pericardial symphysis, since valvular disease is practically always present, and the prognosis following acute rheumatic pericarditis is usually bad except for rare cases without proved valvular deformity in which no cases in this study were seen to have developed Pick's syndrome.

Edeiken, Joseph, and Wolferth, Charles C.: The Heart in Funnel Chest. Am. J. M. Sc. 184: 445, 1932.

Ten cases of moderate or severe funnel chest were studied in order to determine its effect upon the heart. There were nine males and one female. The ages ranged from seven months to sixty-nine years. The deformity was probably acquired in four cases; congenital in five cases, and unknown in one. One case was complicated by a kyphoscoliosis and pigeon breast. Clinically, the latter was the only one who showed evidence of cardiac decompensation, but it is believed this was due to the lung lesions resulting from the spinal deformity. Electrocardiograms were normal in seven uncomplicated cases. Two cases showed evidence of depressed myocardial function. Fluoroscopically the heart was flattened in the anteroposterior diameter and correspondingly enlarged in the anteroposterior view. It was displaced up-

ward and to the left and in one case appeared rotated to the right. Although the heart is displaced, electrocardiograms fail to reveal any consistent variation of the electrical axis, probably because the heart was displaced as a whole.

It is concluded that uncomplicated funnel chest does not appear to have any clearly defined effect upon the functional capacity of the heart unless the deformity is traumatic or of rapid development; the lack of symptoms can probably be explained by the slow development in the vast majority of cases. This allows for accommodation within the chest and heart.

Klotz, Oskar, and Simpson, Winifred: Spontaneous Rupture of the Aorta. Am. J. M. Sc. **184**: 455, 1932.

An analysis is given of five cases of so-called spontaneous rupture of the aorta. A common underlying process was administered in all cases consisting of a peculiar non-inflammatory degeneration of the media affecting the muscle and elastic fibers due to a variety of factors. Similar lesions precede the development of dissecting aneurysms. A peculiar medial degeneration was found aside from spontaneous rupture or dissecting aneurysm with increasing frequency, with advancing age either as a diffuse process or in sporadic distribution through the aorta. The lesions have no relation to syphilis.

Stieglitz, Edward J., and Probst, Duane W.: Differential Arterial Tension. Am. J. M. Sc. **184**: 336, 1932.

The arterial tension was measured in both arms in a series of six hundred individuals ranging in age from eighteen to sixty years. Whenever the difference in systolic tension was 10 mm. Hg or greater or when the diastolic difference was 5 mm. Hg or greater, an asymmetry was declared to exist. The incidence of asymmetry was slightly over 15 per cent of this group. It was found to be more common in persons with elevated arterial tension and in those with vasomotor instability. Sex was not a factor. Elevation of the systolic and diastolic tension was somewhat more frequent on the right than on the left. Arteriolar spasticity, cervical rib, aortitis, injury to an extremity with atrophy, arteriovenous aneurysm and central trophic disturbances as occur in tabes dorsalis, are all factors to be considered in evaluating the causation of persistent asymmetry.

Adams, James M.: Some Racial Differences in Blood Pressures and Morbidity in a Group of White and Colored Workmen. Am. J. M. Sc. **184**: 342, 1932.

A study has been made of 28,221 blood pressure readings on a group of approximately 14,000 industrial employees, between the ages of eighteen and sixty-five years, approximately one-third of whom were colored and the remainder white. All the examinations were made on apparently healthy individuals and were noted on examinations of applicants for employment (9000) and annual health examinations (5000). None were included of individuals who were sick or who consulted for medical advice. An average of three and four-fifths readings at different ages were made of the 5000 employes represented or 19,000 readings and a single reading of the 9000 applicants for employment. The period covered was from 1920 to 1930 inclusive.

From this study the following observations are apparent: The blood pressures of the colored are higher than those of the white. The pressures after forty years of age advanced more rapidly in the colored than in the white. Damage to the aortic valve occurs earlier and more frequently in the colored than in the white. Albuminuria is more often functional in the white persons and more often indicative of nephritis in the colored.

The frequency of illness was the same in both races. The recuperative powers of the colored are less than those of the white. The white race is more susceptible to respiratory and other infections, to gastrointestinal diseases, especially appendicitis and gas-

tric and duodenal ulcers, and to skin diseases, than the colored. The colored men are more susceptible to rheumatic and degenerative diseases than the whites. Venereal diseases and malaria are more prevalent among the colored, probably because of greater exposure and less prophylaxis.

Cheer, S. N., and Dieuaide, F. R.: Studies on the Electrical Systole (''Q-T'' Interval) of the Heart. IV. The Effect of Digitalis on Its Duration in Cardiac Failure. J. Clin. Investigation 11: 1241, 1932.

An electrocardiographic study was made of the action of digitalis on the R-R and Q-T intervals of patients with heart failure. A consistent decrease was found in the length of the Q-T interval in relation to the R-R interval, which was often decreased. This reduction was not always paralleled by a decrease in heart size. It is apparently an important index of the greater efficiency of the myocardium in recovery from heart failure and is interpreted as the result of a direct action of digitalis on the myocardium. The relative length of systole is a good guide to digitalis therapy. The experience of the authors leads them to believe that excessive use of digitalis is no more desirable than insufficient use, and the relative length of systole has proved a delicate guide to the danger of overdosage.

Cohn, Alfred E., and Steele, J. Murray: Studies on the Effect of the Action of Digitalis on the Output of Blood From the Heart. I. The Effect on the Output of the Dog's Heart in Heart-Lung Preparations. J. Clin. Investigation 11: 871, 1932.

The minute output from failing, dilated hearts in dogs in heart-lung preparations is increased when ''therapeutic'' doses of digitalis are administered. The effect is the opposite of that in the case of healthy hearts, normal in size. When the output increases, the pressure in the right auricle decreases. Increase in output is consistent with decrease in the diastolic volume of the heart.

If the inflow and consequently the outflow from the heart is restricted, the decrease in outflow is greater in the failing heart than in the same heart when it acts under the influence of digitalis. It appears from this rest and from the discussion in the text that constriction of the hepatic veins is not a significant factor in the effect which the action of digitalis exerts on the size of the failing heart.

In estimating the value of a drug, its usefulness in therapeutics need not depend on its effect of any given function which presumably is correlated with the effect of that drug on the organism as a whole.

Book Reviews

VERHANDLUNGEN DER DEUTSCHEN GESELLSCHAFT FÜR KREISLAUFFORSCHUNG. Edited by Dr. Bruno Kisch. Dresden and Leipzig, 1932, Theodor Steinkopff.

The transactions of the fifth annual meeting of the German Association for the Study of the Circulation are recorded in a volume of about 350 pages which includes some forty papers. Most of these deal with the two aspects of circulatory disorders chosen for special consideration—disturbances of the arterial blood pressure and of the peripheral circulation. Each of these two topics is introduced by two important *referate* and the whole volume bears testimony to the very substantial character of the work done by the Association. Many of the contributions are deserving of careful study. *L. A. C.*

DIE ERNÄHRUNG DES HERZENS UND DIE FOLGEN IHRER STÖRUNG. By Prof. Dr. med. Luigi Condorelli, Naples. (Ergebnisse der Kreislaufforschung, Bd. III) 230 pages, 70 illustrations. Dresden and Leipsig, 1932, Theodor Steinkopff.

This is the third monograph in a series dealing with various experimental and clinical aspects of cardiovascular problems, published under the editorial supervision of Professor Bruno Kisch, of Köln. As the title implies, the present volume concerns itself with a discussion of the coronary circulation in health and disease. The subject matter is divided into four main parts—anatomy, physiology, experimental pathology and human pathology.

The first three sections, though adequately complete, constitute only about one-half of the volume, and furnish a background for the fuller consideration of the clinical features. The choice of terminology in designating the varieties of coronary disease is open to criticism. The author has chosen to divide all affections of the coronaries into two groups: A, coronaritis, which he calls the "Minor Coronary Syndrome"; B, acute coronary occlusion, designated as the "Major Coronary Syndrome." The term "coronaritis" suggests an inflammatory condition. Yet under this heading is included the large group of disturbances associated with atherosclerosis, as well as the less common lesions caused by syphilis, rheumatic fever, thromboangiitis obliterans, periarteritis nodosa and acute, suppurative infections. Furthermore, a sharp separation into minor and major syndromes, though perhaps helpful for discussion, is artificial, since occlusion is but one type of episode which may occur as the result of coronary disease.

Changes in the form of the electrocardiogram are given full consideration and numerous illustrative records are pictured.

An extensive bibliography is appended to each section, and due credit is given to workers in the laboratories and clinics of England, France, Germany, Austria, Italy, Scandinavia, Russia, Rumania and America. Professor Condorelli has made a critical appraisal of many of the papers cited in a manner which is possible only for one who has himself contributed to the literature in this field. The monograph represents an excellent review and should be of interest to all those who are workers in the domain of cardiology. *R. L. L.*

DER CORONARKREISLAUF: PHYSIOLOGIE, PATHOLOGIE, THERAPIE. By Dr. Max Hochrein. Pp. 227, with 54 illustrations, subject and authors' index. Berlin, 1932, Julius Springer.

This monograph is an excellent summary of the entire subject of the coronary arteries, intended for the physician and investigator somewhat familiar with this field.

The literature is thoroughly reviewed, and the author shows familiarity not only with the German literature but with the foreign as well. The bibliography at the end of each section is very complete.

The author has attempted to present the subject from each of the anatomical, physiological, pathological, and clinical aspects.

The section on the anatomy is up to date. In the experimental section the author lays particular stress upon his own work. His presentation in this and the preceding section is scientific and very critical, although he shows a decided bias toward his own work. Summaries have been provided after each section so that the general reader can glean the information without the difficulty of following the detailed presentation. It is worth-while for the American reader in particular to become acquainted with the author's results and interpretations because he has come to the conclusion that Anrep's theories as to the importance of aortic blood pressure on coronary flow is not correct. According to Hochrein's results the flow is greatest during systole. Apparently he and Anrep are in accord that this is so in the intact animal as far as the superficial coronary arteries are concerned. They still differ in that Hochrein believes that the flow throughout the heart muscle is also greatest in systole, an opinion not held by Anrep. This is not the place to go into the relative merits of the two points of view. However, this study shows that there are still many factors concerning coronary blood flow which we have heretofore somewhat neglected. As a result of his studies Hochrein is inclined to believe that chemical and nervous mechanisms are as important as the mechanical. The controversies presented in this section are not at all surprising when one realizes the difficulties of evaluating the numerous variables which every worker in this field has encountered. In the section following he deals with the pharmacology of the coronary arteries, based again chiefly on the results of his own work.

The last portion of the book deals with the pathological and clinical aspects of coronary disease, in which the author brings out clearly facts accepted by all. He vacillates somewhat as to the presence of "coronary spasm" in diseased coronary vessels. He points out that mitral stenosis, by distorting the sinuses of Valsalva, may lead to narrowing of the mouth of the coronaries and he thus explains angina pectoris in such cases.

In the section on the clinical aspects of coronary disease the author's method changes from the critical scientific presentation used before to an empirical one, based on clinical judgment and personal experience. Case reports are inserted in this portion to illustrate various points. This sudden change in style of presentation has its advantages but confuses the purpose of the monograph. Summaries might have been made in this section of the monograph to aid the reader. In discussing the symptomatology of coronary disease the author presents first the general symptoms and the electrocardiogram, which latter subject is inadequately handled; he then discusses the symptom-complexes associated with coronary disease; namely, angina pectoris, cardiac asthma, and paroxysmal tachycardia. He emphasizes the significance of the personality make-up of the patient in the estimation of anginal pain. He favors the myocardial ischemia hypothesis of angina pectoris, believing, however, that very often the cause for the development of angina is a chemical or nervous action on the coronary vessels. He also suggests that nervous mechanisms may play a rôle in producing cardiac asthma. A discussion of coronary sclerosis, of syphilis of the coronary arteries and of coronary thrombosis follows. The last section of the book is devoted to the therapy of this group of cases.

In viewing the book as a whole one finds that it is apparently intended primarily for the physician especially interested in this field. Despite the appearance recently of several excellent monographs on this subject, there is a place for Hochrein's review because of the breadth of the subject matter covered in each division, and the personal experience which he has had in each of these lines. In other words, this book

is permeated by the author's own experiences; and while it sometimes has a tendency to give a one-sided picture, it serves, nevertheless, to show the interrelation of anatomy, physiology, pharmacology, and pathology in completing the clinical picture of coronary disease. *L. N. K.*

LES MALADIES ORGANIQUES DU FAISCEAU DE HIS-TAWARA. LES SYNDROMES CORONAIRES—L'ENDOCARDITE SEPTALE—L'INFARCTUS SEPTAL. ÉTUDE CLINIQUE ET ANATOMIQUE. By Ivan Mahaim, Privat-docent de la Faculté de Medecine de Lausanne. Pp. 595. Paris, 1931, Masson & Cie.

In this comprehensive treatise an attempt is made exactly to evaluate all previous observations of importance relating to the disturbances of the mechanism of the heart beat produced by organic diseases of the specialized cardiac tissues discovered by His and Tawara, and a large number of original observations, splendidly illustrated with diagrams and microphotographs, are presented in detail.

The first part of the book is devoted to the physiology, anatomy, and histology of the His-Tawara system and to methods of examining its structure and studying its functional integrity. The blood supply receives special attention, and a résumé of the essentials of clinical electrocardiography is included.

The second part is concerned with the correlation of the microscopic lesions found post mortem and the changes in the mechanism of the heart beat observed during life. The first three chapters of this section deal with destructive lesions resulting in conduction defects. After reviewing all of the cases that have been published as demonstrating a relation or lack of relation between atrioventricular heart-block and lesions of the conducting system and describing four of his own cases of complete block in which a complete microscopic examination of this system was carried out, Mahaim draws the following conclusions:

When the continuity of the His-bundle is completely destroyed permanent and complete atrioventricular dissociation is invariably present.

Permanent complete heart-block is always organic in origin.

Complete atrioventricular dissociation is often due to lesions that involve both branches of the bundle rather than the main stem or node of Tawara.

There is no necessary relation between the apparent degree of a partial lesion and the degree of dissociation produced by it. An almost complete lesion may be associated with normal conduction or with an insignificant conduction defect.

Nineteen cases of supposed complete bundle-branch block in which the branches of the bundle were examined histologically are reviewed. Only three of these (the two cases published by Eppinger and Stoerk and one reported by Kauf) are regarded as entirely satisfactory from the standpoint of demonstrating that the lesions discovered were responsible for the electrocardiographic abnormalities observed. Mahaim gives a detailed description of eight additional cases studied by himself. In six of these the continuity of the right branch of the bundle was completely interrupted. The electrocardiograms are reproduced, and all show some degree of left axis deviation. The QRS-intervals range from 0.09 to 0.16 second; the measurements given are 0.11, 0.10, 0.10, 0.09, 0.16, and 0.09 second respectively. With one exception none of these electrocardiograms could be regarded as depicting complete branch block if the criteria in common use were adhered to. In a seventh case both bundle-branches were completely transected by destructive lesions. The electrocardiogram shows auricular fibrillation with a ventricular arrhythmia of the type usually associated with this condition. The ventricular complexes are of small amplitude, and the QRS-interval is given as 0.12 second. Ventricular extrasystoles frequently occurred. According to Mahaim's interpretation complete atrioventricular dissociation is present with an irregular idioventricular rhythm arising in the left bundle branch below the lesion. In an eighth case the left bundle branch was almost completely interrupted. The electrocardiogram shows right axis deviation with a QRS-

interval of 0.10 second. In all of these cases the lesions were multiple, and both branches were more or less involved.

With regard to the electrocardiographic abnormalities produced by complete interruption of the continuity of the right bundle branch, Mahaim concludes that left axis deviation is invariably present; that the QRS-interval is often not prolonged beyond 0.09 or 0.10 second; that the ventricular deflections are frequently of small amplitude, particularly when subdivisions of the left branch are also involved, and that the abnormalities of the T-deflections are proportional to those of the QRS-deflections. He apparently believes that a very large percentage of the curves at present attributed to preponderant hypertrophy of the left ventricle are due to right branch block, complete or incomplete.

Destructive lesions of the right bundle branch, which receives its blood supply by way of the anterior descending branch of the left coronary artery, are almost invariably vascular in origin and are usually associated with lesions of the anterior subdivisions of the left branch, which are nourished by the same artery. Complete lesions of the left branch are almost never vascular in origin, but are usually due to the extension of a valvulitis, involving the aortic or mitral valve, to the septum. The main stem of the bundle is likely to be involved at the same time so that left branch block without complete atrioventricular dissociation is rare.

Four chapters are devoted to lesions of the specialized tissues associated with hyperexcitation, i. e., with attacks of ectopic tachycardia arising in the affected region. Ischemic, inflammatory, or degenerative lesions may act in this way. When the tachycardia is due to lesions of the bundle branches, the ventricular complexes may be polymorphous, or alternation in the form of these complexes may occur. Mahaim apparently believes that digitalis produces ventricular tachycardia of this type only in cases in which organic lesions of the conducting system are present.

The last part of the book deals with the relation of lesions of the conducting system to coronary, myocardial and valvular disease and to congenital anomalies of the heart, particularly defects of the ventricular septum. Mahaim believes that obliterative vascular lesions involving the anterior descending branch of the left coronary artery produce a characteristic syndrome; insufficiency of the left ventricle, enlargement and deformity of the left ventricle, and right branch block. The deformity of the left ventricle, due to aneurysm of the apex and adjacent portions of the wall, may be recognized by roentgen-ray examination.

On the whole this treatise, which ends with a list of over one thousand articles bearing on the subjects discussed, should prove a valuable work of reference. It may be noted, however, that many of the opinions expressed therein are at variance with recent observations that have appeared since it came off the press. If, as now seems practically certain, classical views regarding the electrocardiographic identification of right and left ventricular extrasystoles and right and left branch block must be revised, many of Mahaim's observations become inexplicable and many of his views untenable.

F. N. W